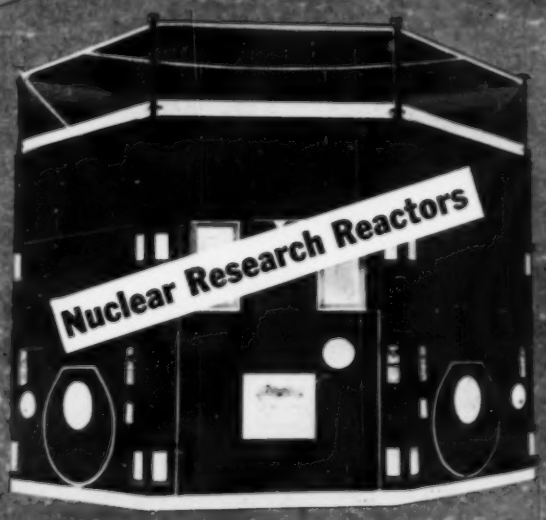
Chemical Engineering Progress

FEBRUARY 1955

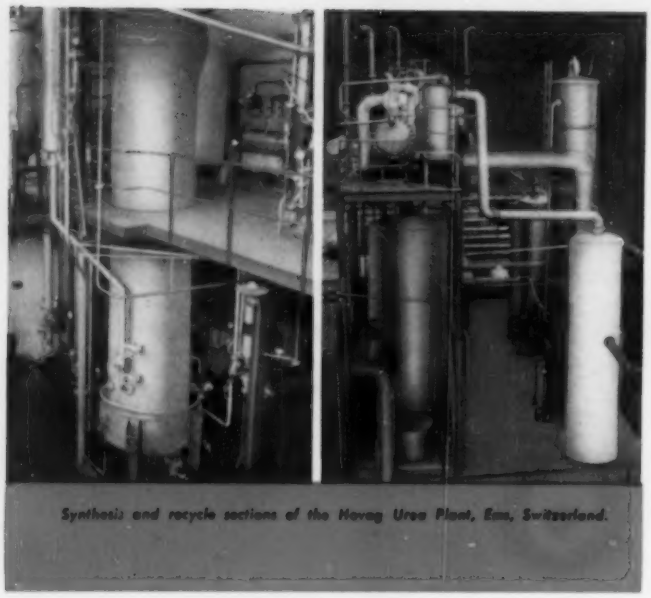
URGENT - DEADLINE FOR INDUSTRIAL REACTOR PROPOSALS APRIL 1.



- what they are
- what they will do
- what they cost

plant location • smog • being a manager • aerosol collection • mixing control • heat transfer • materials properties

product **quality**
process **simplicity...**



Synthesis and recycle sections of the Havag Urea Plant, Ems, Switzerland.

these are reasons why the **Inventa** process for

UREA

is gaining increased recognition...

More and more, attention is being turned to Vulcan Engineering and the Inventa Urea Process. Now the vast potentialities of urea production—for fertilizers, cattle feeds, plastics, pharmaceuticals—can be fully realized. For here is a process which produces *only* top-quality product, suitable for all these applications—and with minimum plant investment.

- The Inventa Urea Process has been thoroughly tested and *proven* in nearly six years' tonnage production.
- A basically *simple* process, it attains high per-pass conversion of ammonia to urea—*without the use of diluents.*
- Commercial operation of the Inventa Urea Process has *demonstrated* a remarkably low level of plant maintenance. This stems from a combination of special materials of construction and operating techniques.
- This all adds up to low initial outlay and long-term operating economy—*plus* the year-around saleability of an all-purpose product!

Engineering and procurement by Vulcan for two major plants utilizing this process are currently in progress. When your company considers urea production let Vulcan Engineering furnish you with more details concerning this valuable process.

VULCAN ENGINEERING DIVISION

The VULCAN COPPER & SUPPLY CO., *General Offices and Plant,* CINCINNATI 2, OHIO

WILMINGTON, DEL. BOSTON HOUSTON SAN FRANCISCO

VICKERS VULCAN PROCESS ENGINEERING CO., LTD., MONTREAL, CANADA

DIVISIONS OF THE VULCAN COPPER & SUPPLY CO.:

VULCAN ENGINEERING DIVISION • VULCAN MANUFACTURING DIVISION • VULCAN CONSTRUCTION DIVISION

Chemical Engineering Progress

FEBRUARY, 1955 • Volume 51, No. 2

Publisher
F. J. Van Antwerpen

Editor
J. B. Mellecker

Associate Editors
R. W. Glasheen
H. R. Glennon

Editorial Assistants
B. R. Hutt H. Pittis
R. M. McCann C. H. Talbott

Advertising Manager
L. T. Dupree

Art Director
Gedeon Takaro

Advisory Board
W. E. Alexander; L. J. Coulthurst; James Donovan; A. W. Fisher, Jr.; J. W. Hemphill; C. G. Kirkbride; G. E. Holbrook; J. J. McKetta; C. R. Nelson; Lloyd Smith; Roland Voorhees

feature articles

nuclear reactors for research 53-F
Manson Benedict

solving conductive heat transfer problems 67-F
R. V. Andrews

growing into management 72-F
R. P. Dinsmore

particle-sizes of aerosols 74-F
G. R. Gillespie and H. F. Johnstone

expansion of the chemical industry 81-F
H. Groppe

interfacial area as a measure of agitation 85-F
T. Vermeulen, G. M. Williams, and G. E. Langlois

activity coefficients of hydrocarbons 95-F
W. C. Edmister and C. L. Ruby

smog 101-F
W. L. Faith

bluegrass country (Louisville meeting) 30
G. J. Schaaf

chemicals to cornfields 40
J. B. Mellecker

new Grace chemical plant 76
Staff

Savannah task force 82
Staff

6	LETTERS TO THE EDITOR	60	NUCLEAR ENGINEERING DIVISION
6	NOTED AND QUOTED	68	INDUSTRIAL NEWS
14	MARGINAL NOTES	80	FUTURE MEETINGS
25	**WHAT'S IN THIS ISSUE**	85	NEWS FROM LOCAL SECTIONS
51—F	**OPINION AND COMMENT**	93	MARKETERS
73—F	ION EXCHANGE ABSTRACTS	95	PEOPLE
104—F	REFERENCE SHEET—LEAD	100	CLASSIFIED
45	DATA SERVICE	101	NECROLOGY
58	CANDIDATES FOR MEMBERSHIP	104	NEWS & NOTES OF A.I.Ch.E.

this month's cover

Orange stripe calls attention to AEC's announcement of 1-10-55, inviting proposals for industrial construction & operation of experimental power reactors—&, as message states, proposals must be with AEC by 4-1-55. Remainder of cover design symbolizes Research Reactors—which author Manson Benedict describes beginning on page 53-F.

—Cover by Milton Wynne Associates.

Published monthly by American Institute of Chemical Engineers at 15 North Seventh Street, Philadelphia 6, Pennsylvania, Editorial and Advertising Offices, 25 West 45th Street, New York 36, N. Y. Communications should be sent to the Editor. Statements and opinions in *Chemical Engineering Progress* are those of the contributors, and the American Institute of Chemical Engineers assumes no responsibility for them. Subscriptions: U. S. and possessions, one year $6.00; two years $10.00 (Applies to U. S. and possessions only.) Canada, $6.50; Pan American Union, $7.50; Other Foreign, $8.00. Single Copies of *Chemical Engineering Progress* older than one year cost $1.00 a copy; others are 75 cents. Entered as second class matter December 9, 1946, at the Post Office at Philadelphia, Pennsylvania, under Act of August 24, 1912.

Copyright 1955 by American Institute of Chemical Engineers.

Member of Audit Bureau of Circulations. *Chemical Engineering Progress* is indexed regularly by Engineering Index, Inc.

Regulate Material Flow to Production Equipment

® DRAVER FEEDERS

You can safely operate sifters, grinders, dryers, elevators and other production machines at maximum efficiency without danger of overloading, when you regulate capacity with a Draver Feeder. You save power and production time, and avoid excessive wear on your equipment.

Illustrated is the "Micro-Master" Draver Feeder, that feeds even stubborn, hard-to-handle materials in a controlled, even stream. Draver Feeders are made in more than 100 sizes and models to feed accurately most all dry powdered, granular and crystalline materials. Original cost and operating expense of Draver Feeders are low, compared with the production losses they prevent.

Draver Feeders will also maintain quality control in blends of dry materials, when used in groups of two or more as a Continuous Mixing System. Ingredients are accurately proportioned and uniformly mixed to assure blends consistently on formula, with minimum production costs.

Send data on your capacity regulating or blending requirements, and our engineers will give you detailed information and recommendations.

FEEDING • MIXING • SIFTING • WEIGHING • PACKING
PACKAGING EQUIPMENT FOR THE PROCESS INDUSTRIES

B. F. GUMP CO.
—Engineers & Manufacturers Since 1872—
1311 S. Cicero Ave., Chicago 50, Ill.

Why Rockwell-Nordstrom Cost Less to Use in ANY

Corrosion control, longer life:

In Rockwell-Nordstrom valves, *the seat is never exposed to corrosive or erosive line materials.* And at all times the plug is surrounded by a tough film of pressurized lubricant to provide:

—a protective coating between plug and body that prevents grinding wear, means longer valve life and easier operation.

—a far tighter seal than is possible with ordinary metal-to-metal closure. Holds lightest gases or heaviest fluids.

—lubricant, forced into a chamber at the small end of the plug, serves as a hydraulic jack, insuring continuous, dependable operation.

And Rockwell-Nordstrom simple quarter turn closure makes power, gear, or wrench operation two to five times faster than ordinary valves. Ideally suited for automation.

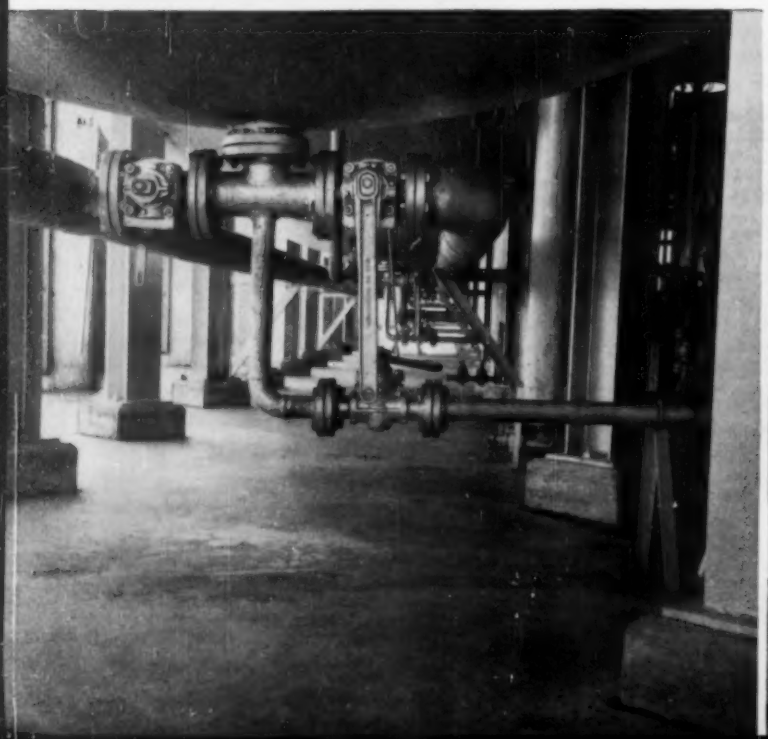
Genuine Rockwell-Nordstrom lubricants:

There are genuine Rockwell-Nordstom lubricants to meet almost any combination of pressure, temperature and line fluid conditions. They are the result of the longest and most extensive research into valve lubricants ever made by any company. Their purpose is to help Rockwell-Nordstrom—the *original* lubricated plug valve—give you the best valve service you have ever had, *at the lowest yearly cost.*

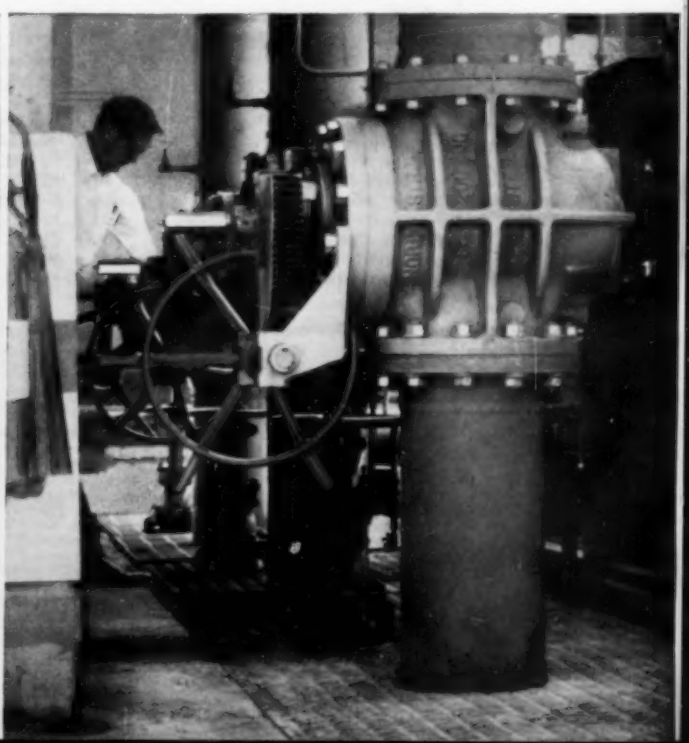
What are your valve problems?

Rockwell-Nordstrom valves are made in a wide range of sizes, pressures, special metals and body designs for chemical and process applications. Your Rockwell-Nordstrom Sales Engineer can help you specify the right valve and lubricant combination for your needs. Or write: Rockwell Manufacturing Company, Pittsburgh 8, Pa.

Wrench operated Rockwell-Nordstroms on these latex tank blowdown lines provide leak proof control under constant operation that would soon ruin ordinary valves.

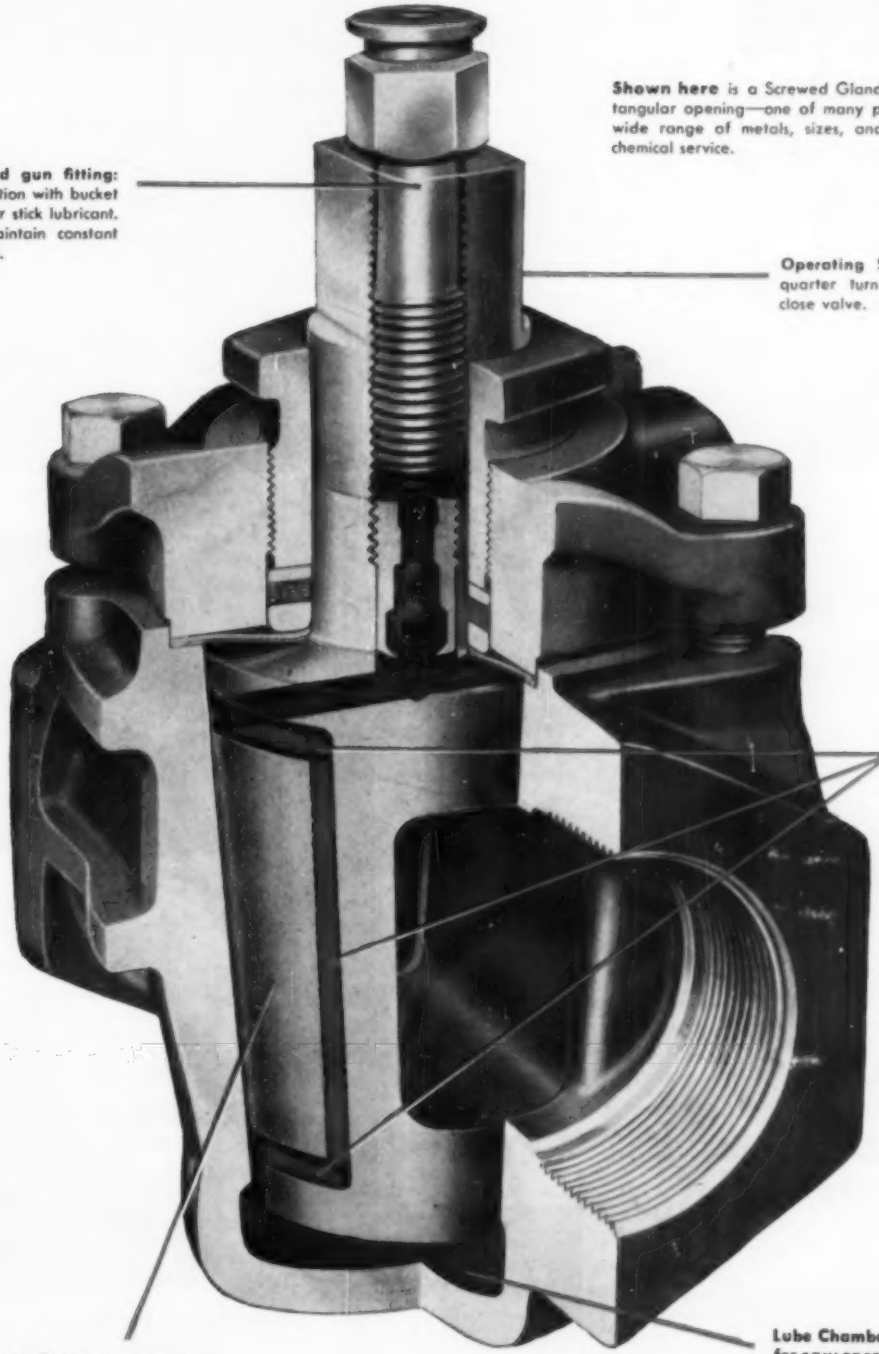


These Rockwell-Nordstrom gear operated valves assure fast, dependable control on dry hydrogen supply lines at a big ammonia plant.



Lubricated Valves

Chemical Process Service



Shown here is a Screwed Gland steel valve with rectangular opening—one of many patterns available in a wide range of metals, sizes, and pressure ratings for chemical service.

Lube Screw and gun fitting: Easy, fast lubrication with bucket gun, hand gun, or stick lubricant. Check valves maintain constant lubricant pressure.

Operating Shank: Quick quarter turn to open or close valve.

Lube Channels: "Sealdport" lubricant system assures perfect seal. Lubricant eliminates metal-to-metal friction.

Tapered Plug: Maximum strength, positive seating, perfect sealing.

Lube Chamber: Jack plug for easy operation, if necessary. No stuck or galled valve down-time.

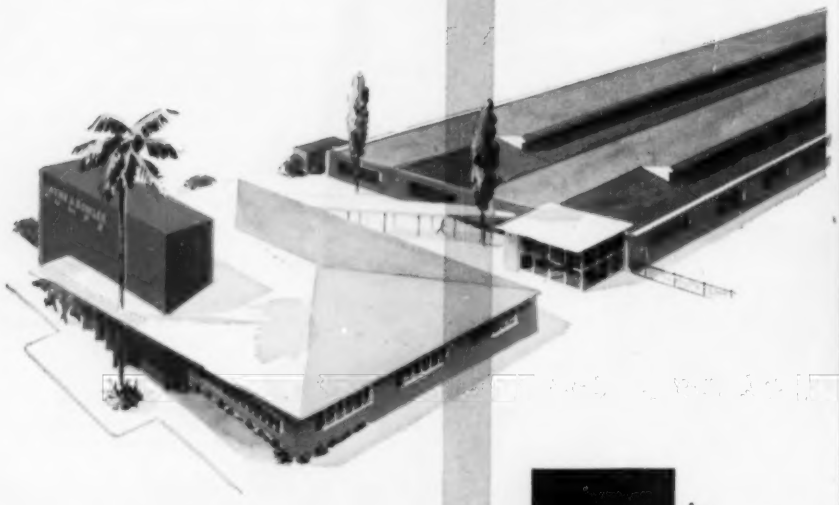
ROCKWELL-Nordstrom VALVES

LUBRICANT SEALED FOR POSITIVE SHUT-OFF

Verti-Line
PUMPS
are made in this new, ultra-modern factory

At Layne & Bowler Pump Company, Verti-Line Turbine Pumps are made to the highest possible standards of quality control . . . In the foundry, iron and bronze castings are poured of metals that are test-proven to be superior . . . In the machine shop every operation must meet the industry's highest inspection standards . . . In the engineering department, every order is reviewed to insure proper selection of a pump that will meet the conditions of the application.

More than 100,000 satisfied vertical pump users agree there's no pump like Verti-Line for low first cost, economical operation, and negligible maintenance.



in the factory

on the farm

for the city

Whatever your vertical pump needs, investigate Verti-Line pumps before you buy.

Send for your free copy of our new booklet, "Pumps For Sale." Ask for Bulletin C-25.

Verti-Line Pumps are the exclusive products of
LAYNE & BOWLER PUMP COMPANY
general offices and main plant
2943 VAIL AVENUE • LOS ANGELES 22, CALIFORNIA

LETTERS TO THE EDITOR

The December Cover

The picture on the front cover of the December issue (1954) was taken at Illinois Institute of Technology by J. H. Nielsen, Mixing Equipment Company Fellow. It illustrates, as shown in the accompanying miniature reproduction, a technique used to study fluid motion in a mixing tank. The photograph shows the movement of small solid spheres in the water discharge stream from a flat-blade turbine

rotated at 300 rev./min. The turbine is shown at the left and the baffle and tank wall at the right. A narrow vertical sheet of light (720 flashes per second) illuminated the spheres in a vertical section of the tank. Fluid velocities can be computed and flow patterns studied from such a photograph.

J. H. RUSHTON
Illinois Institute of Technology
Chicago, Illinois

NOTED AND QUOTED

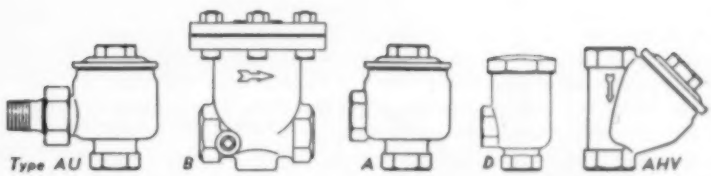
More About Patents

"The process of development in manufactures creates a constant demand for new appliances, which the skill of ordinary head-workmen and engineers is generally adequate to devise, and which, indeed, are the natural and proper out-

(*Continued on page* 10)

NICHOLSON Steam Traps'

1. Initial Cost
2. Upkeep Expense
3. Warm-Up Time
4. Production Time



SIX TYPES FOR EVERY PROCESS, HEAT, POWER USE

¼" to 2" sizes for pressures from vacuum to 300 lbs. Bronze, monel or stainless steel bellows. Bronze, semi-steel or cast steel bodies.

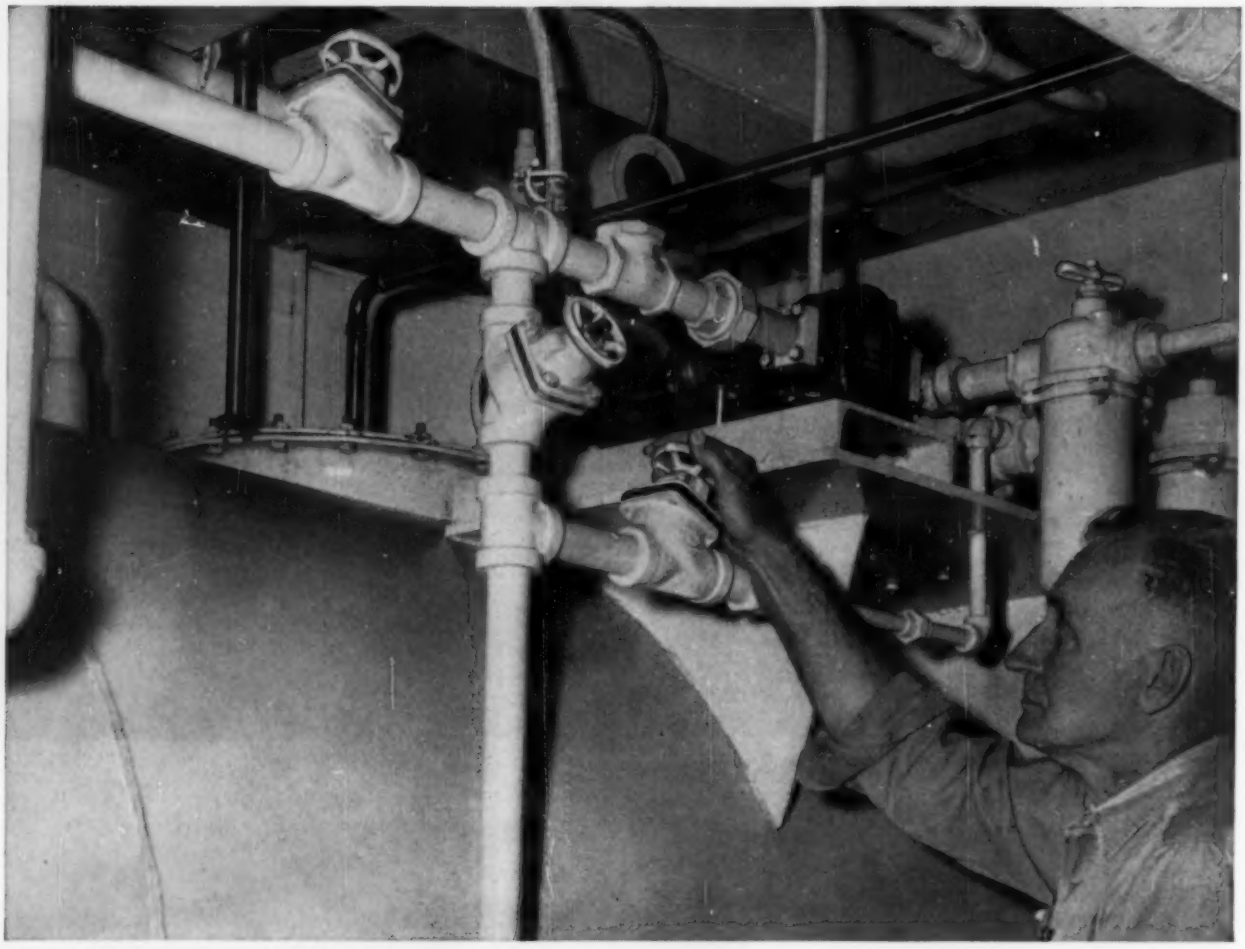
SEND FOR TRAP CATALOG 953

W. H. NICHOLSON & CO.

TRAPS · VALVES · FLOATS

214 OREGON ST., WILKES-BARRE, PA.

Sales and Engineering Offices in 53 Principal Cities



Light oil meets its master in these CRANE VALVES

THE CASE HISTORY— Read how the Johnson & Johnson baby products plant at Cranford, N.J., completely stopped a valve leakage condition that wasted product . . . caused a safety hazard . . . and menaced the plant's high sanitation standards.

Valves formerly used on very light baby oil lines were the source of trouble. Keeping them tight at the stuffing box was next to impossible. Constant servicing of stuffing boxes was necessary, even after repacking every 4 to 8 weeks. Several packings were tried without success while the high maintenance costs and nuisance conditions continued.

Early in 1951 the plant found the solution in Crane No. 1610 Packless Diaphragm Valves. They removed the cause of leakage —immediately stopped its troubles and costs. Almost 4 years later—with no maintenance whatsoever—the Crane packless valves remain absolutely tight; continue giving perfect service. And that goes for all valves added since the first installation.

Crane No. 1610 Packless Diaphragm Valves

When you have valve problems with hard-to-hold fluids, try Crane *Packless* diaphragm valves. They eliminate stem leakage and maintenance on air, vacuum, gas, light oil and similar services. Their diaphragm has longer life, yet should it fail, their separate disc prevents escape of line fluid. Available in wide selection of materials and sizes. Ask for folder AD-1942 or see your Crane Representative.

CRANE CO.

General Offices: 836 S. Michigan Ave., Chicago 5, Illinois
Branches and Wholesalers Serving All Industrial Areas

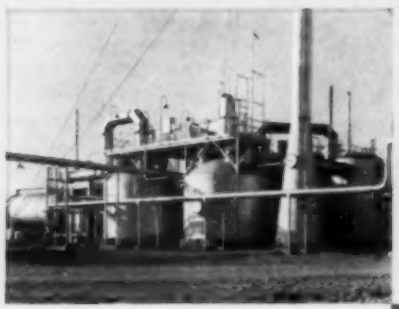
VALVES • FITTINGS • PIPE • PLUMBING • HEATING

CRANE'S FIRST CENTURY . . . 1855-1955

20

SULFUR PLANTS

by... **PARSONS**



75% of the contracts for plants to recover sulfur from H_2S in the United States and Canada during the past two years have been awarded to The Ralph M. Parsons Company.

Now under design for Tide Water Associated Oil Company on the East Coast is the largest sulfur recovery plant ever to be designed. This facility is expected to be on stream in 1956.

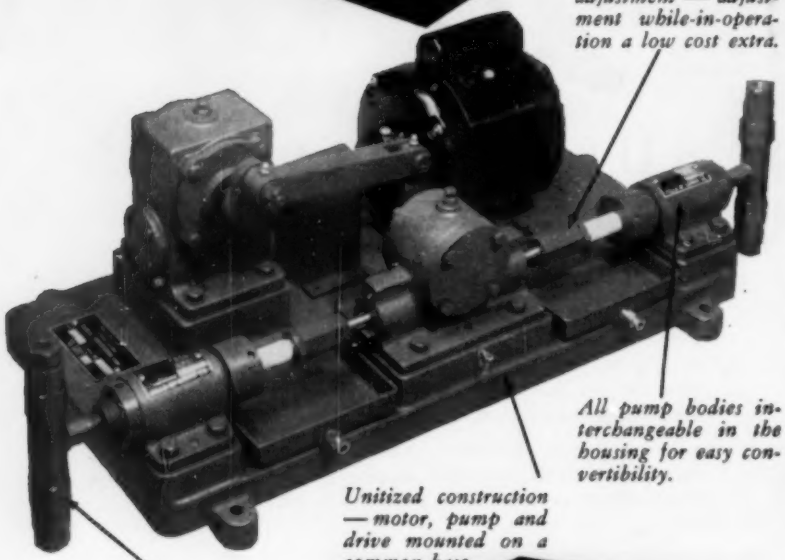
THE RALPH M. PARSONS COMPANY

Engineers • Constructors

617 South Olive Street, Los Angeles 14, California

NEW YORK • TULSA • WASHINGTON • ANKARA • BAGHDAD
BEIRUT • KARACHI • NEW DELHI • PARIS

Can your proportioning pumps match this for convenience and versatility?


Easy, precise stroke adjustment — adjustment while-in-operation a low cost extra.
All pump bodies interchangeable in the housing for easy convertibility.
Unitized construction — motor, pump and drive mounted on a common base.
Separate, interchangeable external check valves for easy dismantling or replacement.

HILLS-McCANNA "U" TYPE PROPORTIONING PUMPS

Hills-McCanna "U" Type Proportioning pumps combine precision operation with high standards of convenience and versatility not ordinarily associated with pumps of this type. The "U" pump is easy to install and can be converted quickly and economically for changing service requirements.

If you must continuously meter or proportion small volume flows with great accuracy, it will pay you to consider a Hills-McCanna "U" Type Pump. Capacities range from 0.10 to 24 gph per feed, 1, 2, 3 and 4 feed units are available.

Write for Catalog UP-54. HILLS-McCANNA CO., 2438 W. Nelson St., Chicago 18, Ill.

HILLS-McCANNA

metering and proportioning pumps

Also Manufacturers of:
SAUNDERS TYPE DIAPHRAGM VALVES
FORCE FEED LUBRICATORS • MAGNESIUM SAND ALLOY CASTINGS

NOTED AND QUOTED

(*Continued from page 6*)

growth of such development. Each step forward prepares the way for the next, and each is usually taken by spontaneous trials and attempts in a hundred different places. To grant a single party a monopoly of every slight advance made, except where the exercise of invention somewhat above ordinary mechanical or engineering skill is distinctly shown, is unjust in principle and injurious in its consequences.

The design of the patent laws is to reward those who make some substantial discovery or invention, which adds to our knowledge and makes a step in advance in the useful arts. Such inventors are worthy of all favor. It was never the object of those laws to grant a monopoly for every trifling device, every shadow of a shade of an idea, which would naturally and spontaneously occur to any skilled mechanic or operator in the ordinary progress of manufactures. Such an indiscriminate creation of exclusive privileges tends rather to obstruct than to stimulate invention. It creates a class of speculative schemers who make it their business to watch the advancing wave of improvement, and gather its foam in the form of patented monopolies, which enable them to lay a heavy tax upon the industry of the country, without contributing anything to the real advancement of the art. It embarrasses the honest pursuit of business with fears and apprehensions of concealed liens and unknown liabilities to lawsuits and vexatious accountings for profits made in good faith.

Justice Bradley
quoted by
Hon. Clarence G. Galston
Federal Rules Decisions

The Meaning of Safety

Cooperation, mutual recognition of necessity, mutual respect, mutual confidence—these are the components of a successful safety program. They are the components of a successful program of any kind.

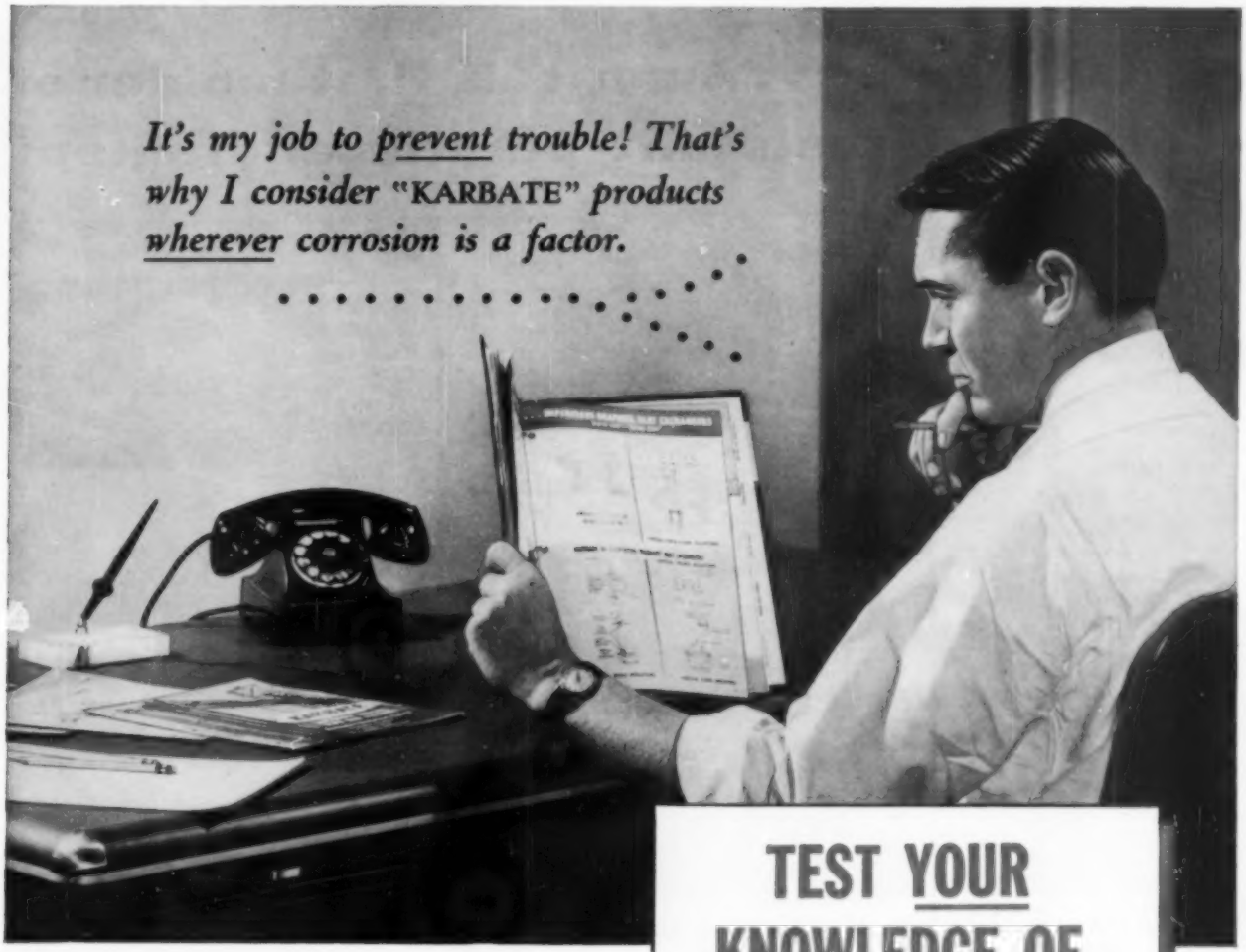
C. H. Greenewalt
"Individual Responsibility"
before National Safety Conference

Forewarned and Forearmed!

The Department of Defense has approximately 35,000 firms on its list of "Planned War Time Matériel Suppliers."

Victor A. Cooley
in *Stanford Research Institute Bulletin*

(*Marginal Notes on page* 14)



TEST YOUR KNOWLEDGE OF KARBATE BRAND IMPERVIOUS GRAPHITE EQUIPMENT

Do You Know...

- ... that "Karbate" impervious graphite is inert to a greater range of corrosive conditions than any other widely used material of construction?
- ... that the price of "Karbate" equipment compares favorably with those of less corrosion-resistant materials?
- ... that standard designs of "Karbate" equipment take full advantage of this material's high compressive strength to assure ruggedness beyond the toughest service requirements?
- ... that "Karbate" brand impervious graphite – the original and most widely used brand—is manufactured exclusively by National Carbon Company?

Don't wait until other materials fail – consider "Karbate" impervious graphite equipment *right from the start* when building a new plant or expanding present facilities. Our technical and engineering staffs are at your service.

The term "Karbate" is a registered trade-mark of Union Carbide and Carbon Corporation

NATIONAL CARBON COMPANY

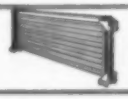
A Division of Union Carbide and Carbon Corporation
30 East 42nd Street, New York 17, N. Y.

Sales Offices: Atlanta, Chicago, Dallas, Kansas City, Los Angeles, New York, Pittsburgh, San Francisco
IN CANADA: Union Carbide Canada Limited, Toronto

Pumps—Catalog Section S-7250

Pipe and Fittings—Catalog Section S-7000

Heat Exchangers—Catalog Sections S-6740 and S-6840

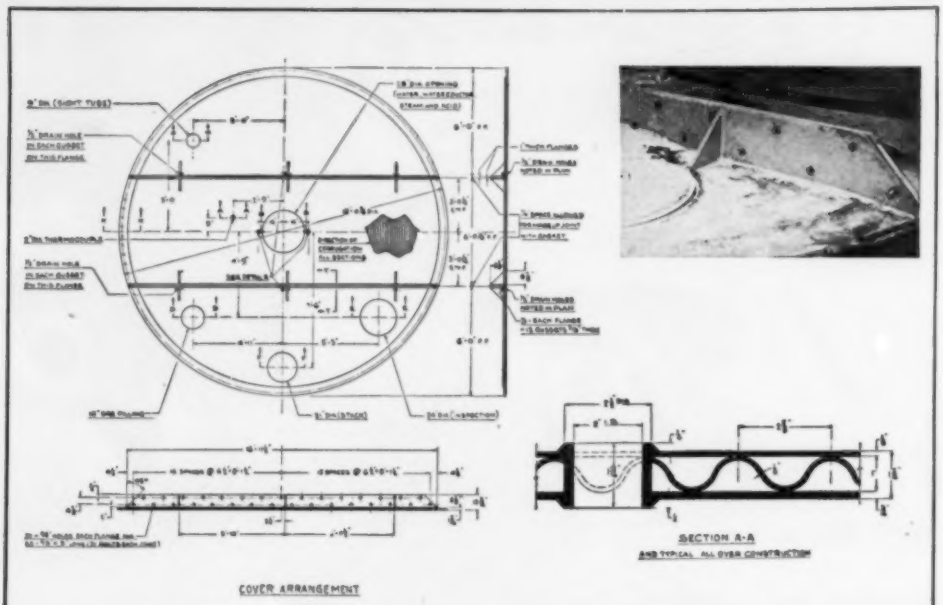

Cascade Coolers—Catalog Section S-8820

HCl Absorbers—Catalog Section S-7460

consult HAVEG . . . America's first molder of corrosion-resistant plastic equipment

P-G TANKS for metal finishing withstand acid attack, are non-conductors of electricity, can take hard knocks.

P-G FUME DUCT is molded into complete fume removal systems. Duct is easily installed, does not require elaborate supports.



HAVEG BUILT THIS P-G COVER FOR AN ACID STORAGE TANK. It replaced a wooden one with a service life of less than a year. A special corrugated reinforcement (see Section A-A) also of P-G, increased the cover's strength, reduced the weight. From design to installation, Haveg engineers worked closely with the plant engineers, made sure by return inspection that true value had been received. In fact, the customer recently ordered another P-G cover for an adjacent tank in the same service.

FOR COOLING TOWERS • FUME DUCT • TANKS • COVERS • LININGS • PIPE

of P-G laminated polyester glass

Both users and manufacturers of cooling towers, and similar structures subject to corrosive liquids and gases, can profit by relying on the accumulated engineering skill of the Haveg Corporation, which is now making polyester glass laminated plastic equipment.

Polyester glass is lightweight, low-cost, easy to fabricate and install. It resists many corrosives. Haveg P-G (polyester-glass) products are satisfactory for continuous operation at temperatures about 200°F., and for intermittent service as high as 240°F.

Molding plastics into corrosion-resistant equipment is not a new venture for Haveg. Over twenty years ago Haveg introduced a new plastic material . . . Haveg . . . made from acid-digested asbestos mixed with special Haveg resins. Haveg has been made into the biggest molded plastic tanks in the world, into a 200′ high fume stack, into giant petrochemical installations.

Like any other construction material, Haveg 41 and 60 and the new P-G materials sometimes present problems in design, manufacture, installation, or economics of selection. In the end, the purchaser must rely on the experience and reputation of the supplier. So Haveg makes these promises:

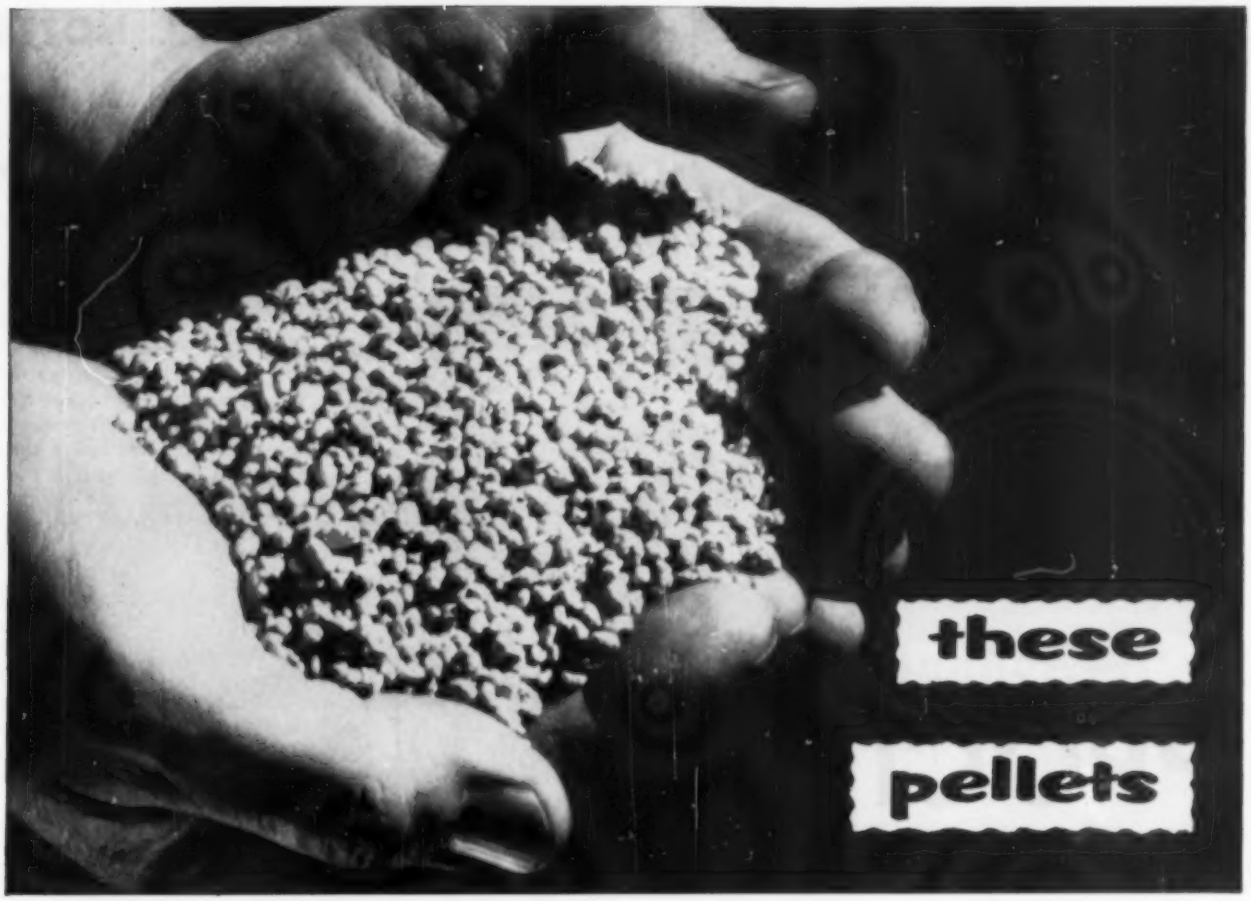
1. Polester glass will be recommended and supplied only after complete testing and full consultation with your plant engineers.

2. Haveg will use its broad experience in fighting corrosion to tell you if P-G is the best material. A reference file of installations plus systematic progress reports where available will be a valuable source of information.

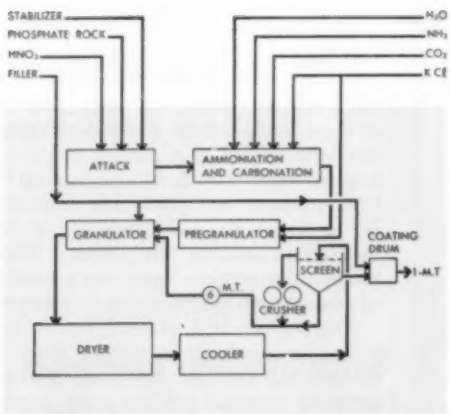
Haveg P-G is new. It promises good dividends in many applications. But it calls for close cooperation between Haveg and the user. Call the Haveg sales engineer listed. Tell us your problem . . . together we will find if Haveg P-G fits your needs!

ATLANTA, Exchange 3821 • CHICAGO 11, Delaware 7-6088
CINCINNATI 36, Sycamore 2600 • CLEVELAND 20, Washington 1-8700
DETROIT 39, Kenwood 1-1785 • HOUSTON 4, Jackson 6840
LOS ANGELES 14, Mutual 1105 • SEATTLE 7, Hemlock 1351
ST. LOUIS 17, Mission 5-1223 • WESTFIELD, N. J., Westfield 2-7383

HAVEG CORPORATION
NEWARK 3, DELAWARE
TRADE MARK REG. U. S. PAT. OFF.
FACTORY: WILMINGTON 8, DEL. • Wilmington 3-8884
A SUBSIDIARY OF CONTINENTAL-DIAMOND FIBRE CO.



could make you rich



PEC Patented Carbonitric Process

More than likely you're looking at complex fertilizer pellets for the first time. *Each* pellet contains balanced quantities of nitrogen, phosphorous and potash, although the units of plant food can be altered to suit the needs of any particular soil.

C&I has the exclusive right to license the PEC* continuous chemical, carbonitric process which produces this superior pelleted fertilizer. C&I will provide a complete and integrated plant or any of the individual units (ammonia, nitric acid, complex fertilizer) for the production of complex fertilizer in any desired capacity. Plants are erected at a fixed price with productions and efficiencies fully guaranteed.

There are still several choice plant-sites available where competition would not exist. Since new economic frontiers do not remain undeveloped for long, now is the time to consider complex fertilizer as an investment in the nation's fastest growing industry.

Specialists in C&I *Processing Ammonia*

* Potasse et Engrais Chimiques

PEC

THE CHEMICAL AND INDUSTRIAL CORP.
CINCINNATI 26, OHIO

Picture YOUR PRODUCT

IN THIS

PROCTOR

CONTINUOUS DRYING RANGE

To improve your product call on Proctor & Schwartz, Inc., who not only manufacture drying equipment, but have the know-how to help you in materials handling problems which arise both in feeding the dryer and delivering your product to subsequent processing equipment.

PROCTOR & SCHWARTZ, INC.
7th STREET & TABOR ROAD, PHILA., PA.

☐ PLEASE SEND BULLETIN 390.
☐ HAVE YOUR ENGINEER CONTACT US.

NAME_____

COMPANY_____

STREET_____ CITY_____ STATE_____

MARGINAL NOTES

A Timely Summary

Mechanism of Polymer Reactions. G. M. Burnett. Vol. III of High Polymers. Interscience Publishers, New York (1954), 493 pages, $11.00.

Reviewed by Edgar L. Piret, University of Minnesota, Minneapolis, Minn.

The many dramatic advances of the last decade in the field of the reaction kinetics of polymerization processes have made the appearance of this reference book timely. The presentation is clear, the mathematical developments are detailed, and there are good descriptions and interpretations of the experimental results obtained by the many investigators referred to.

Research literature in the field of polymer chemistry is painfully voluminous; hence the appearance of this well-organized and summarizing volume will be appreciated by many who are directly engaged in polymer work and also by chemical engineers interested in following recent developments in the field of reaction kinetics.

For Quantity and Quality— A Leader

Heat Transmission, 3 edition. William H. McAdams. McGraw-Hill Book Company, Inc. (1954), 532 pages. $8.50.

Reviewed by R. E. Peck, Head, Chemical Engineering Department, Illinois Institute of Technology, Chicago.

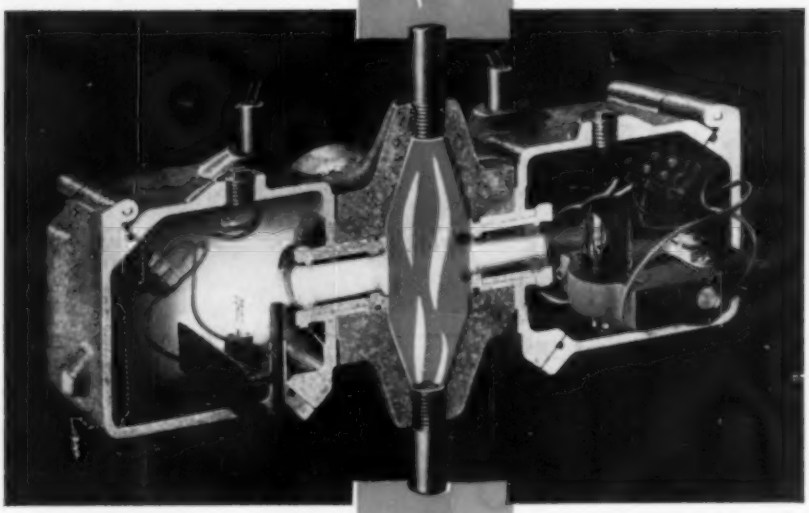
Most engineers are familiar with the first two editoins of "Heat Transmission" by William H. McAdams. The third edition retains the better features of these texts, but the material coverage has been expanded to almost double its original size. The book can be used by both students and practicing engineers for a thorough understanding of the theoretical side of the subject. Heat transfer correlations have been expanded to cover most of the modern literature.

The author still places greater emphasis on applications rather than on theory but he has increased the descriptive material and has made greater use of analytical methods than was made in previous editions.

The chapter, Radiant-Heat Transmissions, by Hoyt C. Hottel is one of the outstanding improvements in the book. This field is one of the most important in chemical engineering and, in my opinion, the text has one of the best presentations of the subject.

(*Continued on page* 19)

Continuous Process Stream Monitoring *with the*



Beckman Industrial Flow Colorimeter

Now many processes dependent on measurement of

- *color intensity*
- *turbidity*
- *chemical composition**

can be continuously monitored and evaluated with this new instrument.

SOURCE A tungsten lamp is the radiation source. Filters select the color of light beamed through the flow cell.

FLOW CELL A stainless-steel casting with windows of ultraviolet-transmitting corex glass handles flows to 7 gpm, pressures to 150 psi. Flow cells can also be glass-lined or made specially from nickel alloys, plastic, etc. Path length can be 1, 2, or 5 centimeters. Openings provide ready access to inside of cell.

RECEIVER A sensitive phototube and exceptionally stable Beckman d-c amplifier measure the radiation transmitted through the flow cell. The amplified signal operates a standard potentiometer recorder. Amplifier circuit components are mounted in three separate plug-in units for immediate on-stream maintenance by regular operating personnel.

for additional information write for Data File 190-35

Beckman *division*

BECKMAN INSTRUMENTS, INC.
FULLERTON 1, CALIFORNIA

**Applies only where color changes with concentration*

Amazingly simple way to MEASURE DEW POINT

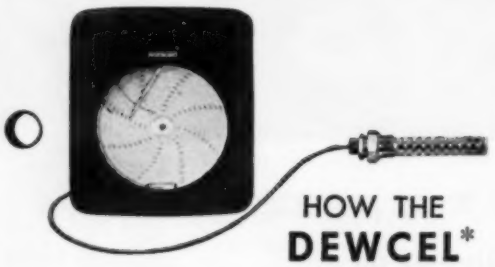
directly . . . accurately . . . continuously

Now you can measure or control the humidity of air or process gases with simplicity and accuracy never before obtainable!

An entirely new-type humidity-sensitive element, the exclusive Foxboro Dewcel*, opens many new possibilities for product improvement in industry. Coupled with a Foxboro Recorder or Controller, the Dewcel offers these outstanding advantages:

1. Direct recording in dew point temperature, at existing pressure.
2. Wide working range — even operates at sub-zero temperatures.
3. Neither adds nor removes water from atmosphere.
4. No water box or circulation of air required.
5. Simplicity that eliminates maintenance.
6. High sustained accuracy.
7. Initial and operating economy.

Investigate Foxboro Dew Point Control for your process. In successful use in nuclear fission, pharmaceutical, food and chemical plants, distilleries, photo film production, drying and storage operations. Write for Bulletin 407. **The Foxboro Company, 932 Neponset Ave., Foxboro, Mass., U.S.A.**



HOW THE DEWCEL* WORKS

The Dewcel element is a thermometer bulb (liquid-filled or electric-resistance type) jacketed with lithium-chloride-impregnated woven glass tape. Over this are wound two spaced gold or silver wires connected to an AC source. The lithium chloride absorbs moisture, allowing current to flow, generating heat, and raising the temperature. Equilibrium temperature is reached when vapor-pressure of the moist salt exactly balances that of the surrounding air or gas. The System translates this temperature into direct readings of dew point.

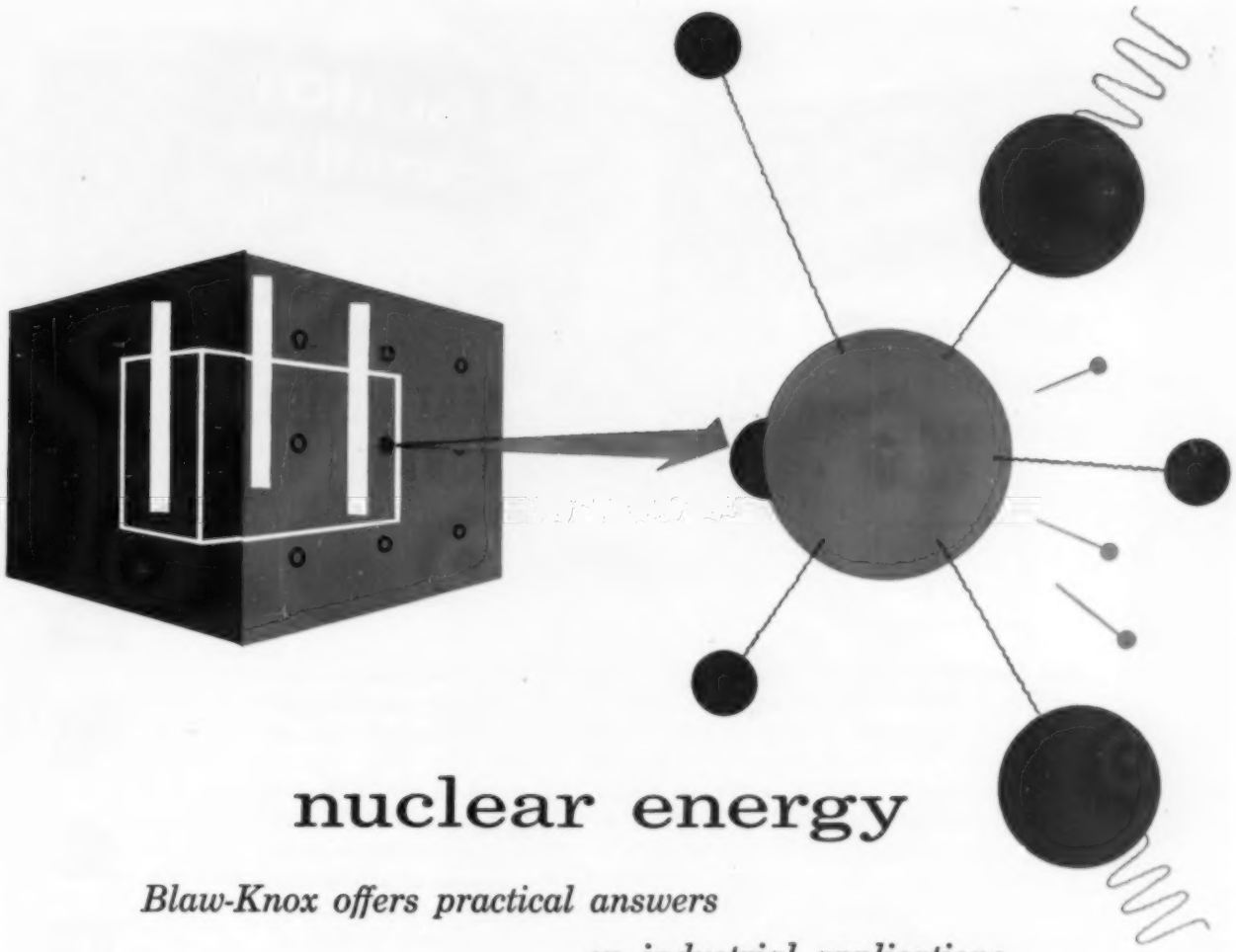
Thus, Foxboro Dew Point Instruments give direct readings or control of dew point from —50°F. to 142°F. at working temperatures from —40°F. to 220°F. Readings easily converted to absolute or relative humidity.

*Trade Mark

FOXBORO
REG. U. S. PAT. OFF.

RECORDING · CONTROLLING · INDICATING
INSTRUMENTS

FACTORIES IN THE UNITED STATES CANADA, AND ENGLAND



nuclear energy

Blaw-Knox offers practical answers on industrial applications

Within recent months, much progress has been made in providing industry with information about the powerful new tool, nuclear energy. In many fields, only the details of commercial application remain to be worked out. To those who take the initiative belongs the competitive advantage.

Exciting prospects are in view—nuclear energy as a source of power—preservation of foods without refrigeration or canning—detection of impurities in quantities as little as one part in a billion—chemical analysis and reaction by neutron activation. This is only the beginning, but it's up to you to take the initiative.

How can nuclear energy be put to work for you? We doubt that anyone can give a pat answer. Each application will require individual study.

The first step is consultation with a firm qualified to advise you. Blaw-Knox has a great breadth of construction and engineering experience on a wide variety of nuclear energy projects, including: *engineering design of the world's first Materials Testing Reactor—engineering of the fuel processing plants for Atomic Bomb projects—ore processing for uranium production.*

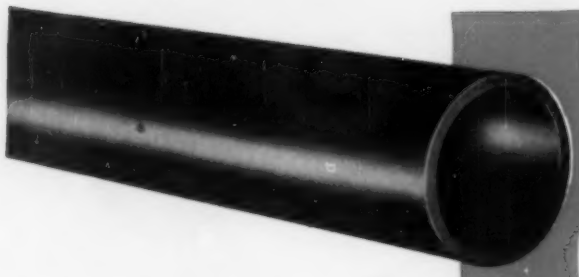
Put this experience to work for you. Blaw-Knox Chemical Plants Division engineers will work with the members of your staff to determine the applicability of nuclear energy to your particular needs. Preliminary consultation will cost you nothing. Why not call Blaw-Knox now?

All reactor development is undertaken in accordance with the provisions of the Atomic Energy Act and subject to the approval of the Atomic Energy Commission.

BLAW-KNOX

BLAW-KNOX COMPANY

Chemical Plants Division
Pittsburgh 22, Pennsylvania
Tulsa 1, Oklahoma/Chicago 1, Illinois
Washington 5, D. C.



for HOT corrosives

ace tempron®

New HIGH HEAT RESISTANT HARD RUBBER

pipe · fittings · chemical parts

Ace Tempron . . . a new synthetic hard rubber for chemical equipment—now offers unexcelled chemical resistance *plus* economy for high temperature applications. In your plant, Tempron can handle many corrosive liquids—*hot*—at costs below other materials you've had to use up to now.

Based on nitrile synthetic rubber (Buna-N), Tempron is *hard* rubber—with better temperature and chemical resistance than hard or soft nitrile rubber compounds hitherto available. Mechanically it withstands temperatures up to 225 deg. F. and higher. Chemically it resists most inorganic chemicals and many organic chemicals and oils at temperatures to 200 deg. F.—and far higher in specific instances. At room temperature it has better resistance to some of the organic chemicals than other rubber and plastic materials.

In one case, Tempron pipe is still in excellent condition after 2 years on hot brine, far exceeding the life of the steel pipe it replaced.

We're now ready with Tempron pipe in 1", 1½", 2", 3" and 4" sizes and fittings in 2", 3" and 4" sizes. Additional smaller sizes of pipe and fittings are under development. We can also—now—produce molded parts, and sheets, rods and tubes from which we (or you) can fabricate a wide variety of parts.

Write today for new bulletin No. 96-A giving full details of Tempron. Or ask for samples and recommendations for your specific applications.

ACE TEMPRON resists:

TESTED AT 200 deg. F.	Hydrochloric Acid, 38% Sulphuric Acid, 50% Phosphoric Acid, 85%	Sodium Hydroxide, 20% Sodium Chloride Ethylene Glycol	Formaldehyde Kerosene Ferric Chloride Stannous Chloride
TESTED AT 78 deg. F.	Benzaldehyde Aniline Pyridine Gasoline	Ethyl Acetate Benzene Toluene Carbon Tetrachloride	Ethylene Dichloride Chlorobenzene Carbon Disulfide Nitrobenzene

ACE rubber and plastic products

AMERICAN HARD RUBBER COMPANY

93 WORTH STREET · NEW YORK 13, N. Y.

MARGINAL NOTES

(*Continued from page* 14)

Most of the material in the recent literature on such subjects as natural convection, exchangers, packed and fluidized systems, high velocity flow, heat transfer in rarefied gases and boiling liquids is presented with references to the articles. The text has a lengthy bibliography and an appendix of tables which are more complete than that contained in most handbooks. The size of some of the graphs however leave much to be desired.

The third edition can be recommended without reservation as a practical reference text or for all courses in heat transfer. The quality of this book should maintain it as a leader in the field for some time.

A Training Course for Welders

Manual For Plastics Welding, Volume II. G. Haim and J. A. Newmann. The Industrial Book Co., Cleveland (1954), 128 pages, $6.00.

Reviewed by Allan G. Folsom, Bolta Products, Division of General Tire & Rubber Co., Lawrence, Mass.

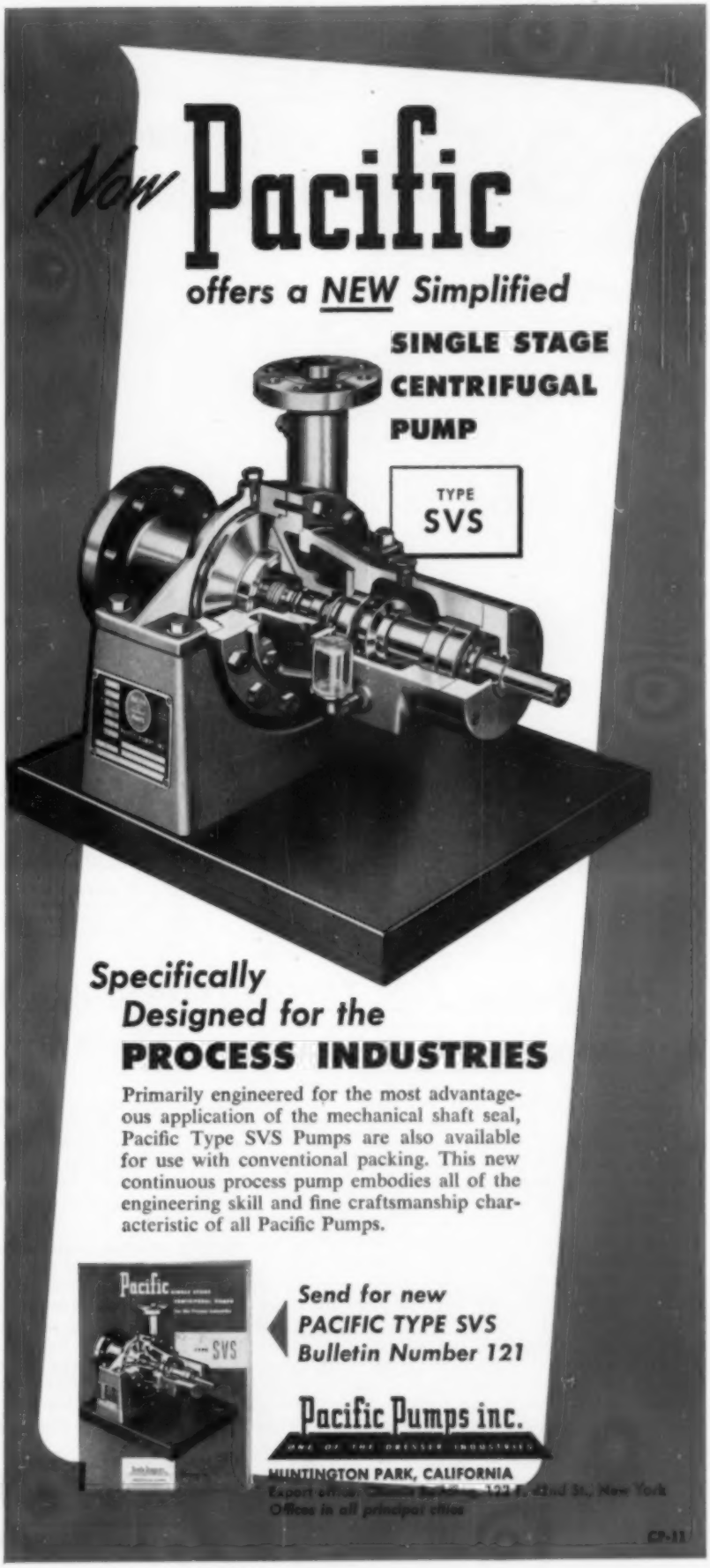
During the past few years the fabrication of corrosion-resistant equipment from plastic materials has become a nationwide industry, the development of which was made possible by the establishment of hot-gas welding procedures. A factual handbook of techniques and training methods for plastic welders has been greatly needed and "Manual for Plastics Welding" supplies this need.

Volume I was devoted to general information of interest to technical executives. Details necessary to develop a trained welder of polyethylene is contained in Volume II.

Important information on the nature and properties of the basic polyethylene material is presented in the first three chapters. Molecular structure, thermal degradation, the effect of ultraviolet light, chemical resistance, and environmental cracking are more than adequately covered.

A short history of the welding of plastics is set forth in Chapter IV. Chapter V is devoted to the equipment necessary for setting up a plastic fabricating shop. The heart of the book is contained in Chapters VI through IX which cover the actual welding technique, type of welds, and general rules for machining, threading, and finishing polyethylene.

The lining of tanks is thoroughly discussed in Chapter X and Chapter XI deals with the installation of polyethylene pipe lines.


Now Pacific
offers a NEW Simplified
SINGLE STAGE
CENTRIFUGAL
PUMP
TYPE
SVS
Specifically
Designed for the
PROCESS INDUSTRIES
Primarily engineered for the most advantageous application of the mechanical shaft seal, Pacific Type SVS Pumps are also available for use with conventional packing. This new continuous process pump embodies all of the engineering skill and fine craftsmanship characteristic of all Pacific Pumps.
Pacific
SVS
Send for new
PACIFIC TYPE SVS
Bulletin Number 121
Pacific Pumps inc.
HUNTINGTON PARK, CALIFORNIA
Offices in all principal cities
CP-11

Meet the man you can call with confidence to solve your thermal insulation problems

To insulate outdoor tanks with complete weather protection, these skilled J-M applicators follow a specification developed by Johns-Manville. Here they are fastening J-M Asbestocite* Sheets over J-M Zerolite* Insulation. J-M 85% Magnesia Insulation is also widely used for this type of equipment

He is your J-M Insulation Contractor... the man with the world's most complete insulation engineering service

"Insulation is no better than the man who applies it." Today, with rising fuel and maintenance costs, it is especially important to place your insulation job in skilled hands. The scientific application of J-M quality insulations by J-M Insulation Contractors will assure you of the maximum return on your insulation investment for years to come. Moreover, you get undivided responsibility for *all* your insulation requirements.

1. You get dependable materials--Johns-Manville manufactures a complete line of insulations for every service temperature from minus 400F to plus 3000F. From them your J-M Insulation Contractor can select the right insulation for the most dependable service on your job. To develop new and improved insulation materials Johns-Manville maintains the J-M Research Center—largest laboratory of its kind in the world.

2. You get dependable engineering—For 95 years Johns-Manville has been accumulating insulation engineering experience. J-M Insulation Engineers are called upon to solve insulation problems of every type and magnitude, in every industry. Since your J-M Insulation Contractor works closely with J-M Insulation Engineers, he brings to *every* job a high degree of training, skill and experience.

3. You get dependable application—Johns-Manville has set up a nationwide organization of J-M Insulation Contractors to serve you. These Contractors maintain staffs of insulation engineers as well as skilled mechanics thoroughly trained in J-M's proved application methods. You can have absolute confidence in their ability to apply J-M insulations correctly for trouble-free performance.

For further information and the name of your J-M Insulation Contractor, write Johns-Manville, Box 60, New York 16, N. Y. In Canada, 199 Bay St., Toronto 1, Ont.

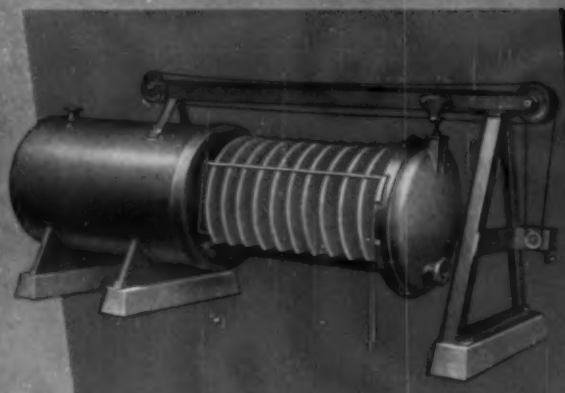
*Reg. U. S. Pat. Off.

Johns-Manville *FIRST IN* INSULATION

MATERIALS · ENGINEERING · APPLICATION

Equipment for

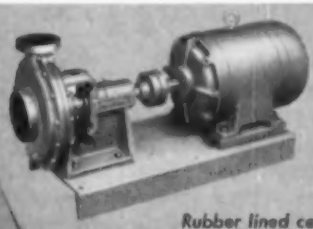
CHEMICAL PROCESS INDUSTRIES



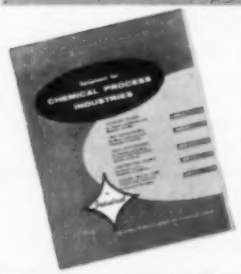
Horizontal and vertical pressure filters in a wide range of sizes for solution clarification and recovery of solids. Special filtration systems are engineered to meet unusual conditions.

Heat transfer equipment engineered to individual requirements for heating or cooling corrosive and noncorrosive liquids and gases.

Standard models and specially engineered ion exchange units for water purification and treatment of solutions.



Rubber lined centrifugal pumps for corrosive and noncorrosive solutions.



Get this NEW Catalog

Complete information on this equipment for chemical process industries by INDUSTRIAL

Ask for Catalog No. CEC-55

5163

Tanks, pipe, and fittings are lined in our own plant with vulcanized rubber for corrosion prevention.

INDUSTRIAL FILTER & PUMP MFG. CO.

5904 OGDEN AVENUE, CHICAGO 50, ILLINOIS

New

Take a ~~closer~~ look at what's required to make High Pressure Tubing to handle

30,000 psi

Pressures of 30,000 psi are accepted industrial practice today. They are not only representative of the advances in alloy tubing technology and manufacture, but also of the tremendous strides taken by the industries in which these elevated pressures are everyday working practice.

As pressures advance so must manufacturing techniques. For example, B&W was called upon recently to manufacture a special alloy tubing for polyethylene equipment based on Croloy 12 (AISI 410), to prevent product contamination. Special manufacturing and inspection techniques were involved in the production of the tubing which was cold finished to size. It was then heat-treated to obtain 100,000 psi yield strength, which could have been considerably higher except for the fact that toughness was desired to meet the dynamic service stresses encountered in operation. A sample of the tubing then was tested to 80,000 psi and, in order to force rupture at this pressure it was necessary to remove half of the wall thickness by machining. This destructive testing was made to insure satisfactory working conditions *at pressures of 30,000 psi.*

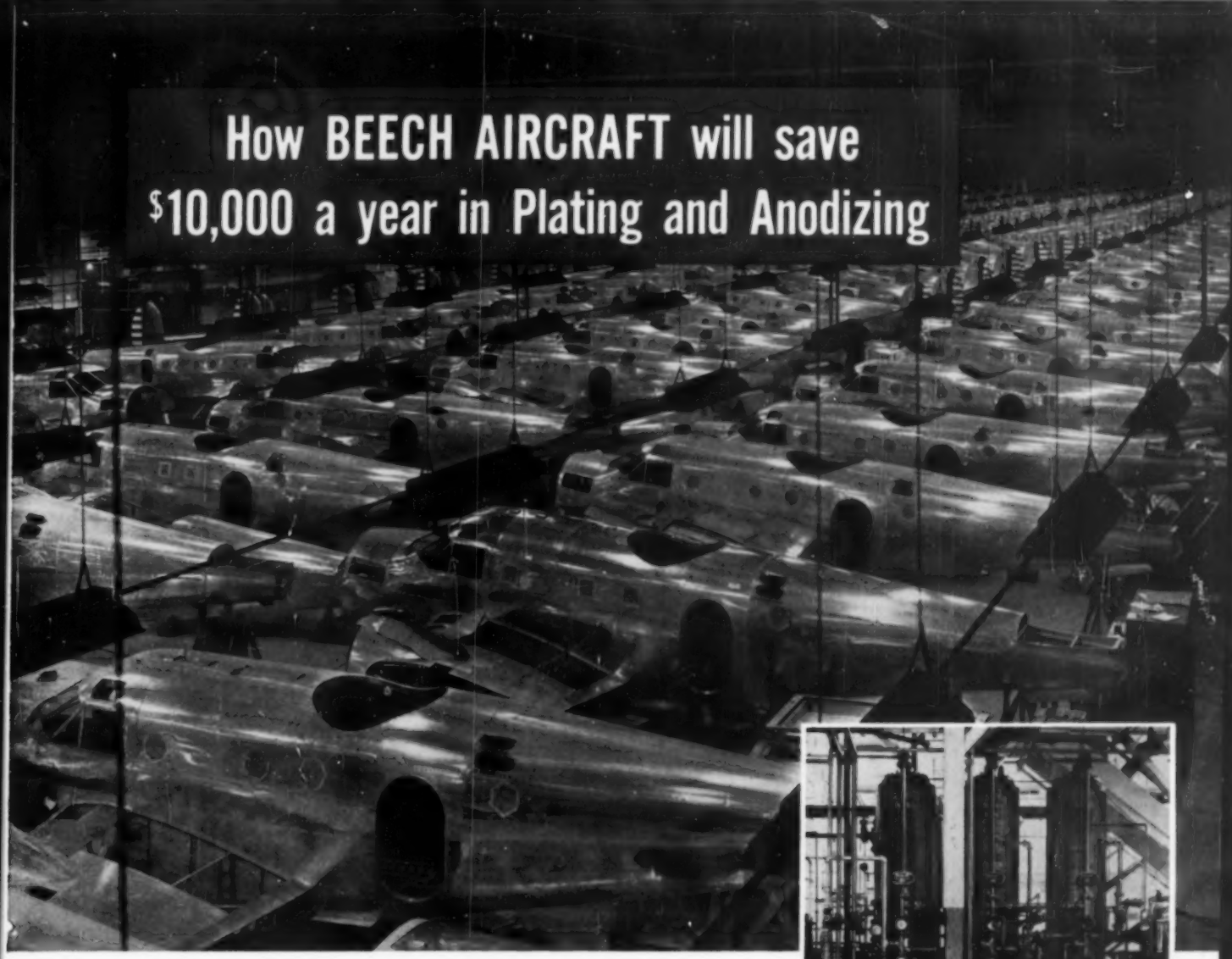
This example, while fulfilling the needs of a specific purpose, serves also to indicate the scope of techniques and facilities you'll find at B&W. Today, with laboratory testing of alloy tubing reaching 200,000 psi, the experience and knowledge of those called upon to make a test a *working reality* are of prime importance. You'll find both at B&W. Call on Mr. Tubes any time to help you meet your needs — standard as well as special.

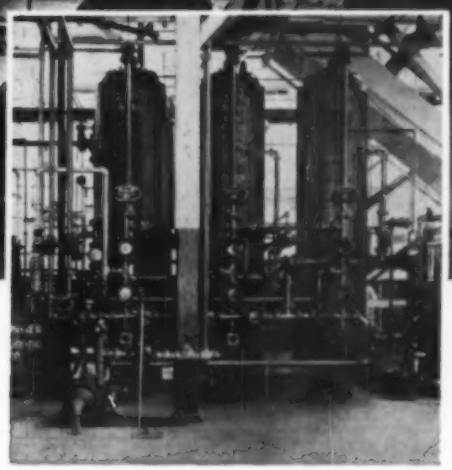
THE BABCOCK & WILCOX COMPANY
TUBULAR PRODUCTS DIVISION
Beaver Falls, Pa.—Seamless Tubing; Welded Stainless Steel Tubing
Alliance, Ohio—Welded Carbon Steel Tubing

B&W SEAMLESS and WELDED TUBES

TA-4065(SSP)

How BEECH AIRCRAFT will save $10,000 a year in Plating and Anodizing





Permutit Ion Exchangers also eliminate waste disposal problem . . . improve resistance to corrosion of anodized coatings.

Beech Aircraft encountered a tough chromate disposal problem. Dumped portions of Beech's 5% CrO_3 anodizing baths plus the rinse flow were sending more than 70 pounds of CrO_3 per day to waste. Immediate action was necessary!

Conventional treatment was no help . . . it takes up too much space, costs a lot. And raises the new problem of sludge disposal.

New Method Investigated! Beech engineers looked into the ion exchange process of chromate treatment pioneered by Permutit. Here's what they got with Permutit's help.

Chromic Acid Savings! Compact Permutit units (above) eliminate pollution. It is no longer necessary to dump any portion of the anodizing baths! The cation exchange unit removes contaminating dissolved aluminum, permits indefinite re-use of the chromic acid.

Improved Corrosion Resistance! The two anion exchange units recover up to 40 lbs. of CrO_3 per day from rinse water. All water is recirculated! It goes back to rinse tanks *mineral-free*, at the correct pH for best resistance to corrosion of the anodized coat.

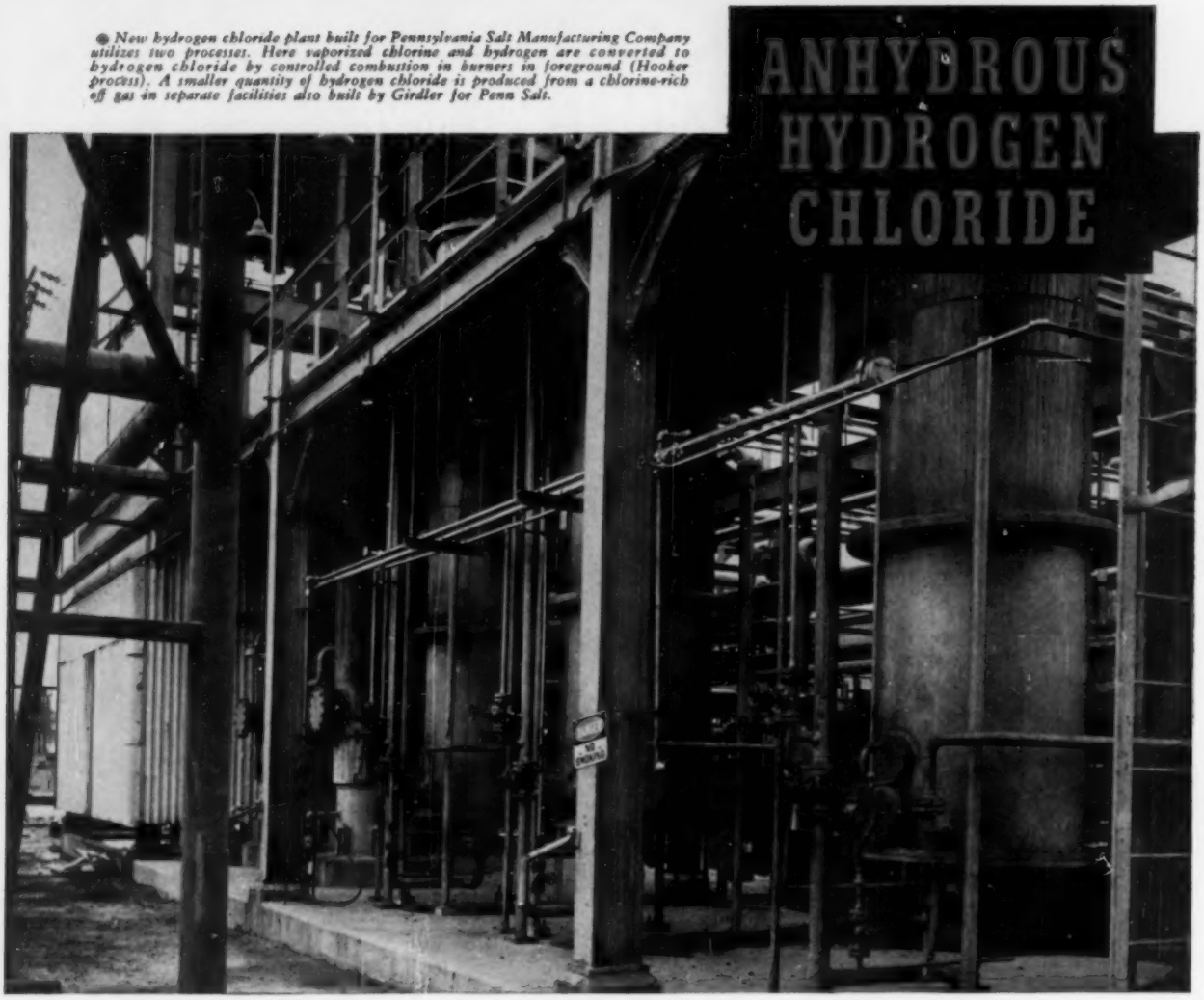
It's easy to see how this Permutit installation will pay for itself in less than 2 years . . . and why you should let Permutit help you solve your waste disposal problem.

Write to The Permutit Company, Dpt.CEP-2, 330 West 42nd Street, New York 36, N. Y., or Permutit Company of Canada, Ltd., 6975 Jeanne Mance St., Montreal.

ION EXCHANGE HEADQUARTERS FOR OVER 40 YEARS

PERMUTIT

● *New hydrogen chloride plant built for Pennsylvania Salt Manufacturing Company utilizes two processes. Here vaporized chlorine and hydrogen are converted to hydrogen chloride by controlled combustion in burners in foreground (Hooker process). A smaller quantity of hydrogen chloride is produced from a chlorine-rich off gas in separate facilities also built by Girdler for Penn Salt.*



GIRDLER-built plant gives uniformly high yields

GIRDLER hydrogen chloride plants (Hooker process) are notable for efficient operation, and high purity yields. Under an agreement with Hooker Electrochemical Co., Girdler designs, builds, and licenses these plants.

For process projects such as this, Girdler assumes unit responsibility for all phases of the work—design, engineering, and construction. Thus coordination and sound results are assured. Take advantage of Girdler's experience in gas processing—call the nearest Girdler office for complete information.

GIRDLER DESIGNS processes and plants
GIRDLER BUILDS processing plants
GIRDLER MANUFACTURES processing apparatus

GAS PROCESSES DIVISION:

Chemical Processing Plants
Hydrogen Production Plants
Hydrogen Cyanide Plants
Synthesis Gas Plants
Carbon Dioxide Plants
Gas Purification Plants
Plastics Materials Plants
Sulphur Plants
Acetylene Plants
Ammonia Plants
Ammonium Nitrate Plants
Hydrogen Chloride Plants
Nitric Acid Plants
Fertilizer Plants
Catalysts and Activated Carbon

the GIRDLER Company

A DIVISION OF NATIONAL CYLINDER GAS COMPANY
LOUISVILLE 1, KENTUCKY

GAS PROCESSES DIVISION: New York, Tulsa, San Francisco. *In Canada:* Girdler Corporation of Canada Limited, Toronto

what's in this issue...

you may be interested in—

Get Your Reactor - (p. 53-F); A famed nuclear authority -- Manson Benedict -- tells what one needs to know in considering installation & operation of research reactors -- versatile tools for radiation & heat production -- which will enable private organizations to evolve industrial application for nuclear energy . . .

Heat & Pipe Lines - (p. 67-F); Pipes buried in the ground or side-by-side can have their heat transfer rates more easily calculated . . . according to Andrews (Tex A & M) . . .

Managers - (p. 72-F); Ray Dinsmore of Goodyear (director of A.I.Ch.E.) writes on the intensely human world the young engineer-manager-of-tomorrow finds himself in -- upon arriving at the first job . . .

Ion Exchange - (p. 74-F); Descriptions of some of the articles appearing in the Institute's recently published book on the subject . . .

Mists - (p. 74-F) are now "measurable for size" and are reproducible in the lab -- for collection device effectiveness studies . . . Authors Gillespie & Johnstone (U. Ill.) checked their artificial sulfuric acid mists against that of an operating contact plant -- and found close comparison . . .

Chemical Industry Expansion - (p. 81-F); Groppe (Monsanto) explains that the Petrochem industry "will continue its high rate of growth, increasing its share of total chem production beyond the 50% it now represents" . . .

Liquid Mixing - (p. 85-F) effectiveness measurement can now be accomplished by a photoelectric device -- described by Vermeulen, Williams & Langlois . . .

Hydrocarbons - (p. 95-F) being processed involve mixtures having physical properties difficult to predict . . . W. C. Edmister & C. L. Ruby (California Research Inst.) offer a more accurate method...

Smog - (p. 101-F); Expert Larry Faith (Air Pollution Foundation & director A.I.Ch.E.) gives us a progress report on the Los Angeles study . . . Points to the auto as a major culprit . . .

Bluegrass Country - (p. 30); Beautiful setting for major Institute meeting at Louisville March 20-23 . . . Y'all Come . . .

Chemicals to Cornfields - (p. 40); How National Distillers is succeeding at launching a fertilizer chemicals plant in the heart of America's richest growing land . . .

Big Nuclear Events Coming! - (p. 60); Giant EJC Congress & A.I.Ch.E. Atomic Exposition slated for December at Cleveland Auditorium . . .

Grace's First Plant - (p. 76); Its twins NH_3 & urea -- near Memphis, Tenn. . . .

Savannah River Revealed - (p. 82); The tremendous task force -- how it was organized and what it did -- is described by G. M. Read, chief engineer of DuPont . . .

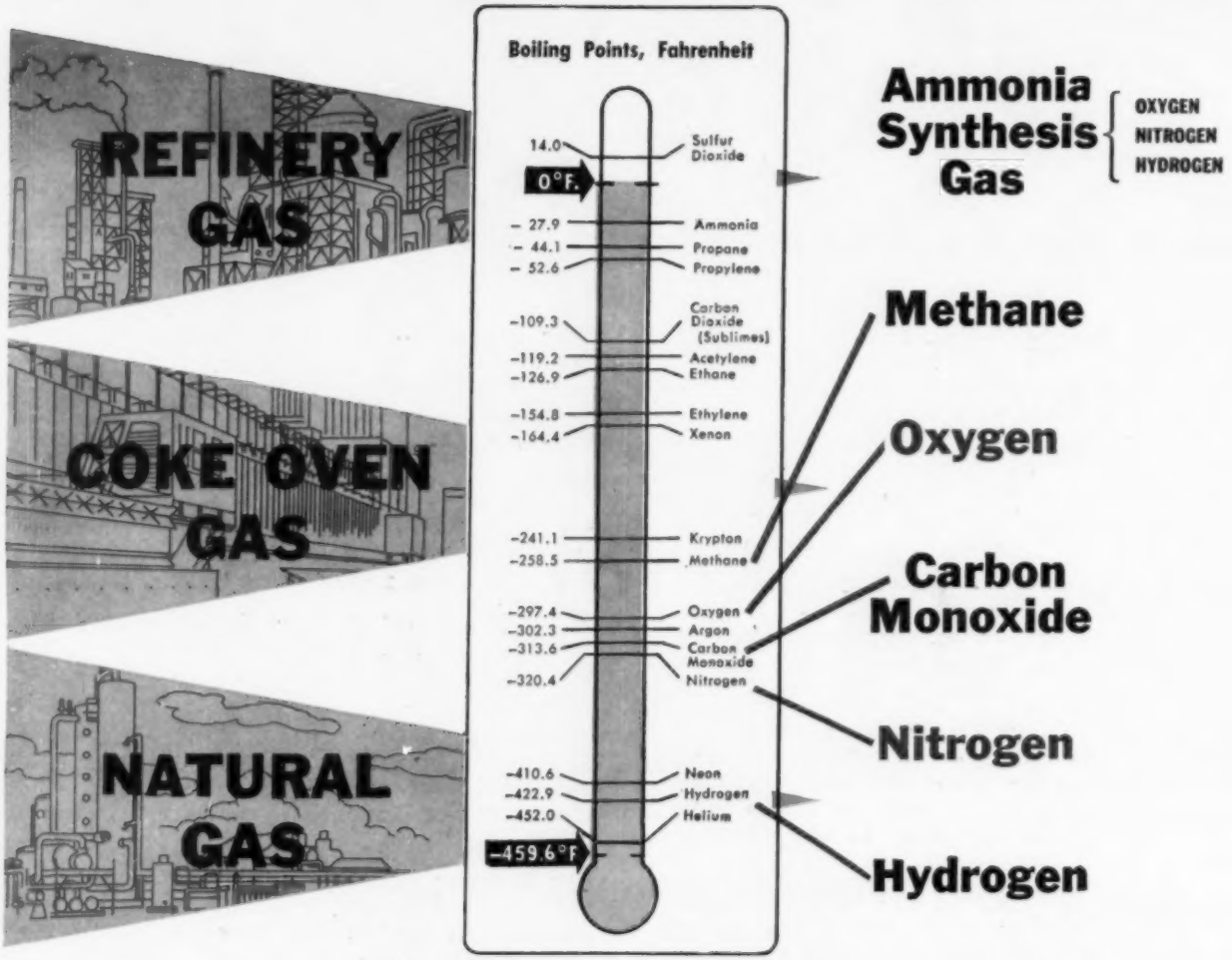
Fluidized Solids - (p. 90) one-day meeting at Brooklyn Poly was addressed by industrial specialists . . . Co-sponsors were N. Y. & N. J. A.I.Ch.E. Sections . . .

Olin Mathieson's - (p. 96) new sulfuric acid plant exit gas scrubbing process has increased productive capacity as much as 20% . . .

K.Y.U.T.D. - (p. 104) means "keeping you up to date" about goings-on within your Institute . . . Read F.J.V.A.'s "News & Notes" . . .

J.B.M.

HYDROCARBON SEPARATION
by Low-Temperature Processing



IF YOUR COMPANY is among the many who are looking into the extra profit possibilities "hidden" in your fluid flows or by-product gases, in natural gas or in the air itself—check with *Air Products.* The low-temperature route is proving to be the most profitable for more and more separation processes. For example, many ammonia manufacturers — both petro-chemical and coal chemical—are using low-temperatures to produce oxygen and nitrogen . . . purify hydrogen . . . recover valuable by-product hydrocarbons.

Ask *Air Products* to investigate the possibilities of your hydrogen, hydrocarbon-rich streams. Leader in its field, *Air Products* has designed and built close to 700 low-temperature gas separation plants. Our more than 100 engineers are at your service. We can supply a preliminary engineering analysis, or a complete process design. Outline your problem to us—your inquiry will incur no obligation. *Air Products, Inc., Dept. U, Box 538, Allentown, Pa.*

36-page BROCHURE explores the broad possibilities of low-temperature processing . . . illustrates *Air Products'* facilities. Write for a free copy.

Air Products
INCORPORATED
Specialists in Low-Temperature Processing

Cost Analyses • Process Design • Apparatus Design • Apparatus Manufacture

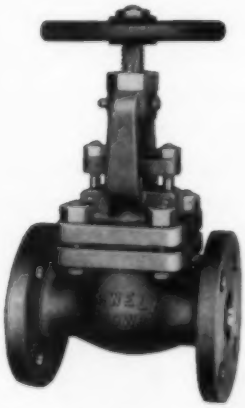
POWELL VALVES . . . THE COMPLETE QUALITY LINE . . . POWELL VALVES

. . . THE COMPLETE QUALITY LINE . . . POWELL VALVES . . . THE COMPLETE QUALITY LINE . . .

FIG. 2342—Flanged End Bolted Cap Swing Check Valve for 150 Pounds W.P.

POWELL CORROSION RESISTANT VALVES

FIG. 2495—Double Disc Flanged End O.S.& Y. Gate Valve for 150 Pounds W.P.



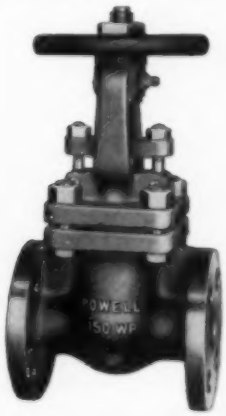


FIG. 2475—Stainless Steel O.S.& Y. Globe Valve for 150 Pounds W.P.

FIG. 3003SS—High Pressure Service Alloy Steel Gate Valve for 300 Pounds W.S.P.

POWELL VALVES . . . THE COMPLETE QUALITY LINE . . . POWELL VALVES

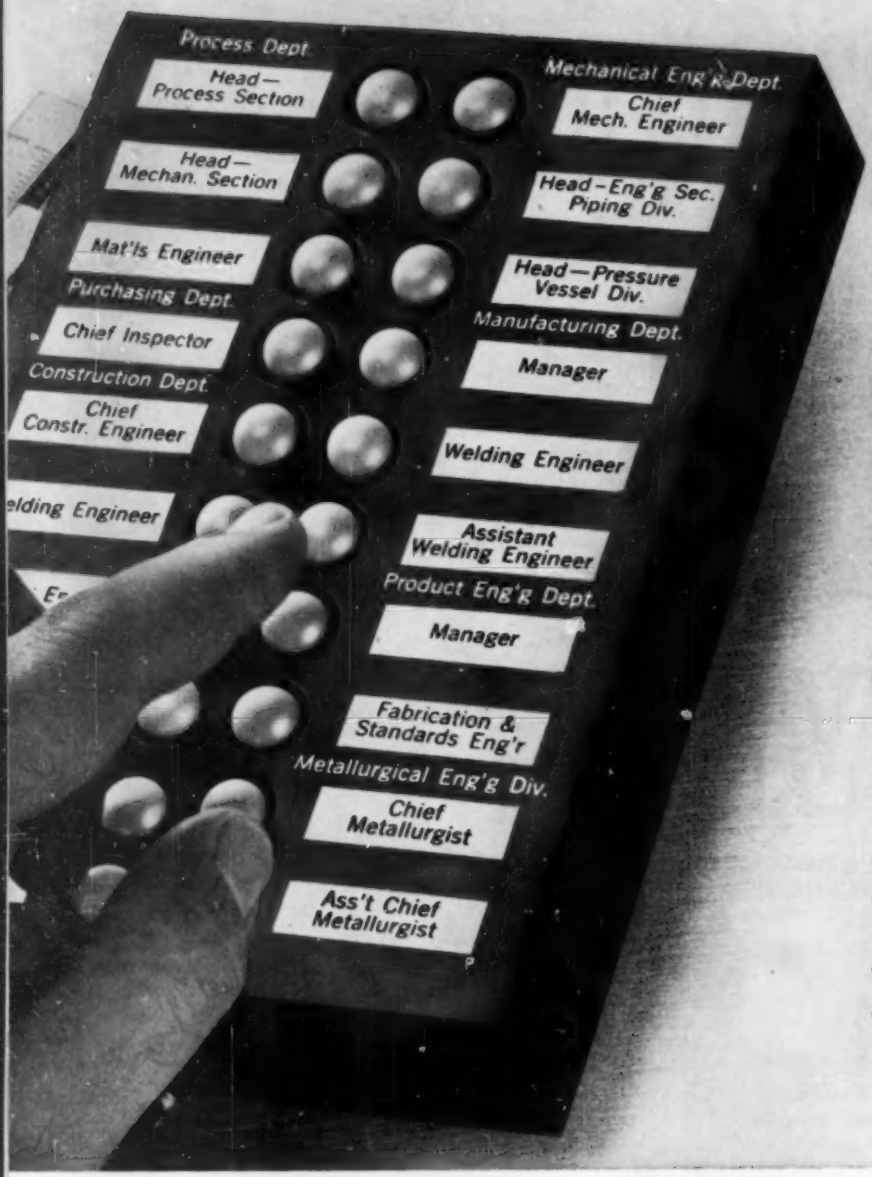
Powell can supply exactly the corrosion resistant valves you need . . . in a WIDE VARIETY of metal and alloys and all designs. You can be certain that every Powell Valve will give you dependable flow control.

Shown above are a few Powell Corrosion Resistant Valves. Investigate these . . . and the *complete* Powell line of quality valves that have a proven record of long, dependable service.

If no distributor is near you, we'll be pleased to tell you about our complete line, and help solve any flow control problem you may have. Write . . .

The Wm. Powell Company, Cincinnati 22, Ohio . . . . . 109th year

High Pressure Answer Men

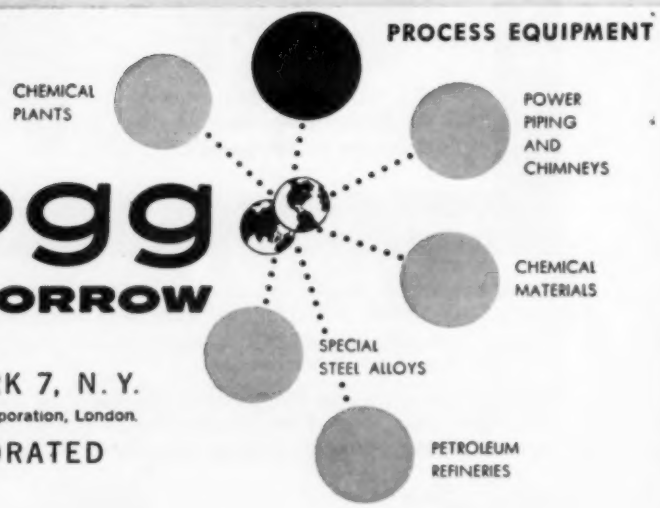


Increasingly high pressures and temperatures used in processes today demand the most advanced engineering and metallurgical treatment of the piping and equipment to handle them. The M. W. Kellogg Company has earned a long-standing reputation in this specialized engineering area.

Largely responsible for M. W. Kellogg's position is the company's "Committee on Materials and Fabrication" which meets regularly to discuss developments of pure and applied research as they concern service experience, metallurgical progress, welding techniques, and improved methods of fabrication.

Composed of principal engineers from M. W. Kellogg's process engineering, mechanical engineering, and construction departments, as well as the Fabricated Products Division, this Committee benefits all of the company's activities and the facilities they offer in their respective fields.

The Committee on Materials and Fabrication is one reason why The M. W. Kellogg Company is recognized as the leader in the design and fabrication of piping, pressure vessels, heat exchangers, waste heat boilers, and process equipment requiring transient and maintained pressures and temperatures.



M.W. Kellogg

ENGINEERING FOR TOMORROW

THE M. W. KELLOGG COMPANY, NEW YORK 7, N. Y.

The Canadian Kellogg Company, Limited, Toronto • Kellogg International Corporation, London

SUBSIDIARIES OF PULLMAN INCORPORATED

opinion and comment

Censors and Pressure Vessels

The Government's recently announced program to bring about voluntary withholding from publication of unclassified but strategic data by the newly organized Office of Strategic Information has brought forth strong comment from the nation's press. As presently organized under the direction of Karl Honaman (from Bell Telephone Laboratories), the OSI is to study ways and means of having informal censorship, and is to report its recommendations to the Secretary of Commerce—who is to transmit these along to the National Security Council. What may happen then is of such importance, that consideration of possible reasons for setting up the OSI in the first place, may be in order.

The decision for this action is said to have come from the President, based on the recommendation of the National Security Council. This body is made up of the president, vice-president, secretaries of state and defense, and the directors of foreign operations administration and office of defense mobilization. According to the *U. S. Government Organization Manual 1954-55*, the "duties of the Council are to assess and appraise the objectives, commitments, and risks of the United States in relation to our actual and potential military power, in the interest of national security . . ." Accordingly, this group should have the most thorough picture available of what the world situation is, and what lies ahead for our nation.

What, then, is the relationship to be construed from the NSC advising the president to establish measures for keeping information which is militarily not classified as sensitive, from becoming available to unfriendly foreign nations?

Recalling statements on the subject of security by Morse Salisbury, director, Division of Information Services, A.E.C. at our Nuclear Engineering Congress in Ann Arbor last June, may now prove thought-provoking at this latest turn of events. Salisbury at one point quoted from the *Information control policy of the U. S. Atomic Energy Commission* as having appeared in the *8th Semiannual Report of the AEC*. He read, "A clear solution to this [secrecy] dilemma would only be possible if it were known exactly when the U. S. might have to defend itself in another war. If it were to be next year, there should be virtually complete secrecy; if it were certain that there would be no war for 30 years, virtually all secrecy should be abandoned."

Salisbury continued his quotation, "In view of the current international situation, a middle course is evidently necessary—a course which will make it possible for the U. S. to defend itself with vigor and success if it is attacked within the next few years, and yet a course which can be followed for many years without seriously weakening our democracy or our science."

We repeat for emphasis, this quotation was read in June, 1954, and was qualified at the time by Salisbury who said, "This policy [on information control] still stands."

It now appears likely that the policy of the middle course has been changed and that many are afraid of "weakening of our democracy and science." On the other hand, perhaps the *broad* policy of the middle course hasn't really changed, and there are other reasons behind the OSI venture.

In a matter of such tremendous consequence, an explanation will surely come forth. In the meantime, we can only wonder, from Morse Salisbury's friendly attempt to explain the workings of our Government to us, what really is going on.

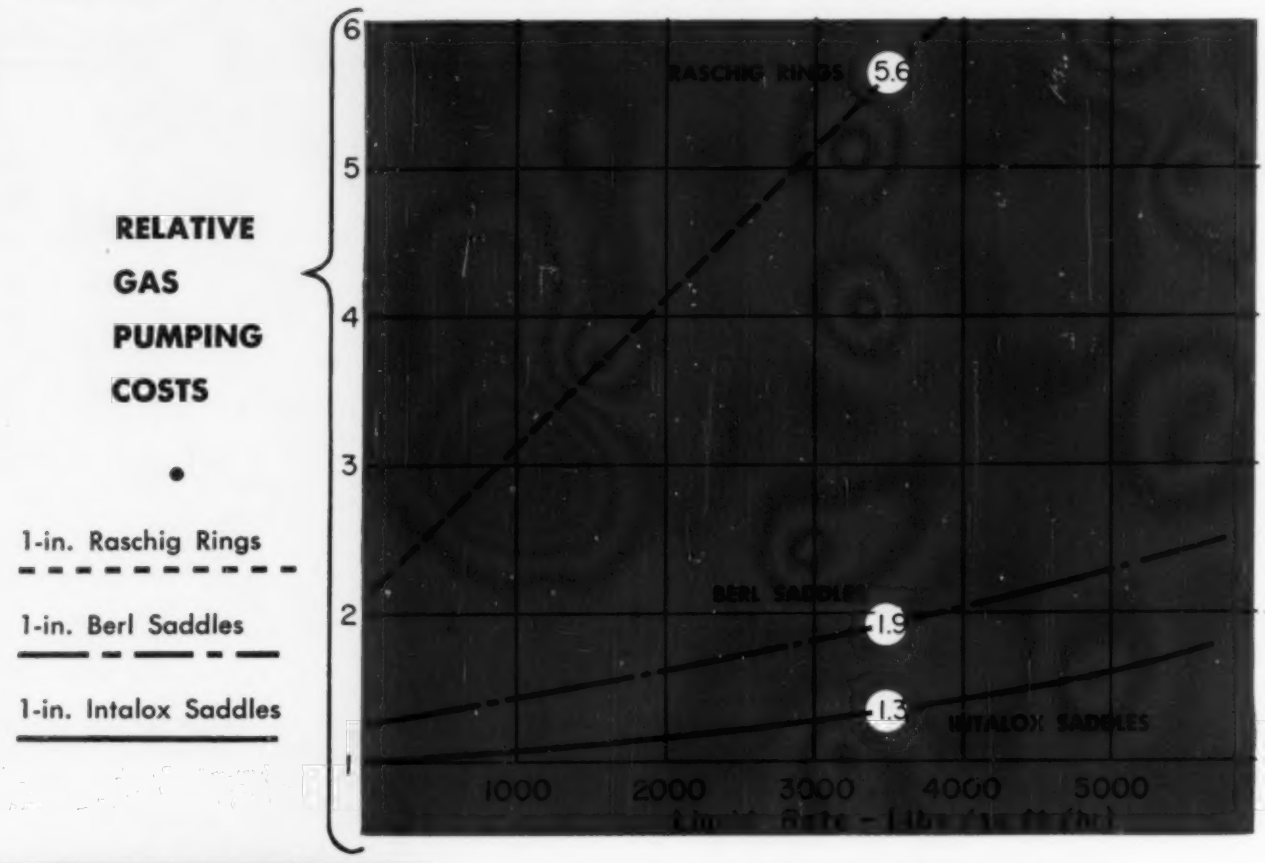
Word has reached us of a major process equipment fabricator deciding to extend its facilities to make possible the production of large plate vessels in wall thicknesses to five inches. As far as we know, there are only four other major plants in the U. S. capable of routinely producing large vessel processing equipment designed to withstand such pressures. This, we believe, is a very salutary event which will have an important bearing on decisions in the future as to the construction of high pressure processing units.

J.B.M.

HOW TO SAVE $$$$ IN GAS PUMPING COSTS WITH INTALOX SADDLE TOWER PACKING

The sharply lower pressure drop characteristics of Intalox saddles effectively reduce tower operating costs in a number of ways. Particularly striking are the savings possible in gas pumping costs. Not only can the savings in initial investment in pumps, blowers, etc., be considerably less, but operating costs, due to lower horsepower requirements, are substantially lowered. For example, if we assume three towers of equal packed height—one packed with 1" Raschig rings, one with 1" Berl saddles and one with 1" Intalox saddles—each scrubbing, say, 700 lbs./sq. ft./hr. of inert gas with 3,500 lbs./sq. ft./hr. of liquid, a glance at the chart below shows the relative gas pumping costs for the Raschig ring packed tower is 5.6; for the Berl saddle packed tower, 1.9; and for the Intalox saddle packed tower, only 1.3.

The saving is actually even greater than it appears. The use of Intalox saddles can result in a reduction in tower height of as much as 30% in new tower design, which further reduces gas pumping costs, thus compounding the savings.



ORIGINAL LOW PRESSURE DROPS MAINTAINED

A low initial pressure drop is of little value if the packing spalls and crumbles under normal usage. Voids quickly fill and pressure drops rise abruptly. The unique shape of Intalox results in a rigid, interlocking bed with minimum thrust on tower walls and with a minimum tendency to shift and "grind." This, plus the high inherent mechanical strength of the ceramic bodies from which Intalox is made, holds pressure drops at their original low level and keeps packing replacement costs down.

Write for a copy of Intalox Saddle Packing Bulletin IS-29.

U. S. STONEWARE

AKRON 9, OHIO

68E

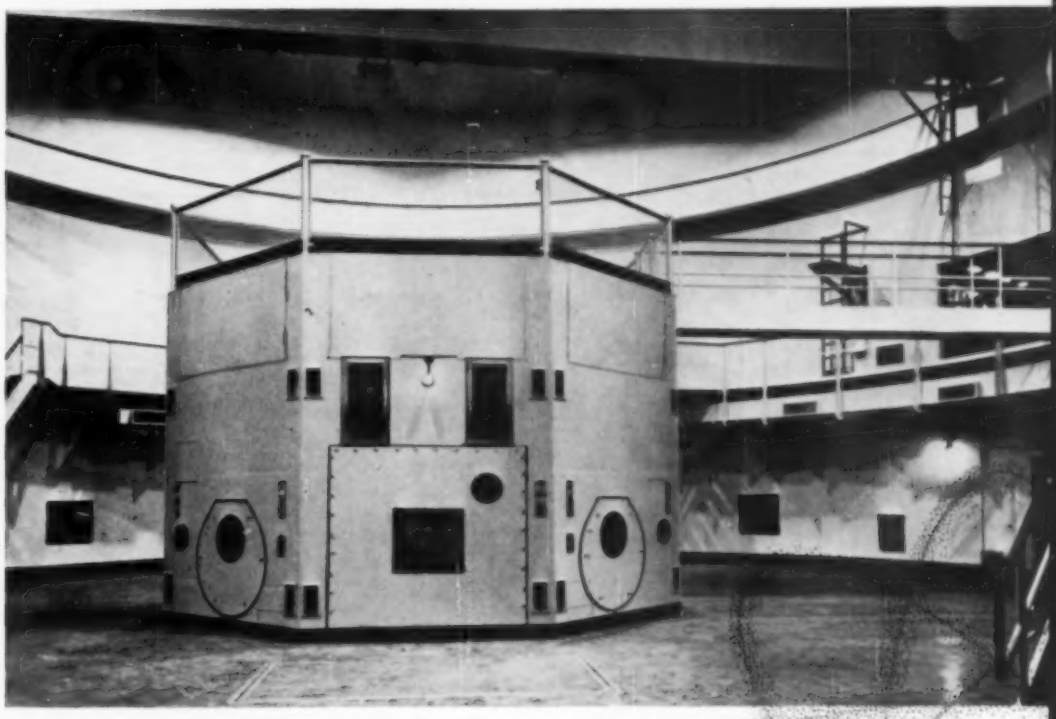


Fig. 10. CP-5 Heavy Water Reactor, Argonne National Laboratory. *Courtesy Argonne National Laboratory.*

nuclear reactors for research

Manson Benedict | Massachusetts Institute of Technology, Cambridge, Massachusetts

The enthusiastic response to President Eisenhower's recent offer of 100 kg. of U^{235} to the United Nations for the construction of research reactors in foreign countries dramatically highlights the value of these new research tools and the widespread interest in their use. It seems timely to give an up-to-date account of the many valuable research uses which can be made of nuclear reactors and of the types of reactors which are available.

Many factors are responsible for the growth of interest in research reactors. The usefulness and versatility of the reactor as a research instrument is becoming recognized. Engineering firms are simplifying the design of research reactors and reducing their cost. The recent revision of the Atomic Energy Act makes it easier to own and operate a reactor and to profit from discoveries made with it. Interest in nuclear power will increase demand for research reactors for reactor physics measurements and for testing components of power reactors. Enriched U^{235}, the key to cheap, powerful research reactors, is in relatively liberal supply, as indicated by the offer of 100 kg. to the United Nations. This is enough to build at least fifteen research reactors and to keep them running for many years. In view of all these favorable factors, research reactors should come into widespread use by research institutes, industrial concerns, and universities, perhaps on a cooperative, regional basis.

This paper discusses briefly how research reactors work, the uses to which they may be put, the types of reactors available, their cost, and their safety problems.

how research reactors work

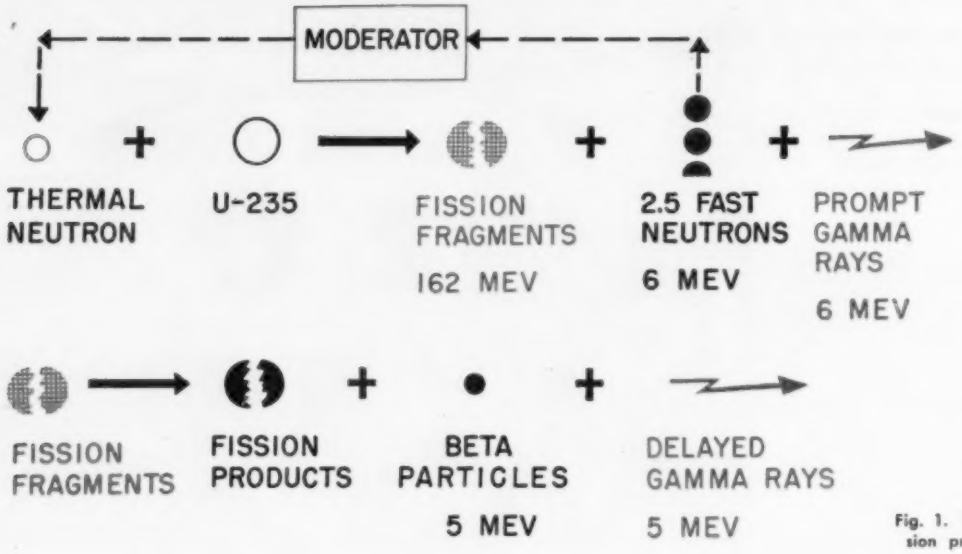


Fig. 1. The fission process.

THE FISSION PROCESS

A research reactor is valuable primarily as a source of neutrons and gamma radiation. In most research reactors these are produced by causing U^{235} to undergo nuclear fission by reaction with thermal neutrons, that is, neutrons with energies corresponding to room temperature. The processes which take place in such a "thermal" reactor are shown schematically in Figure 1.

In the primary fission reaction an atom of U^{235} absorbs a thermal neutron and splits into two fission fragments carrying 162 million electron volts (Mev.*) of kinetic energy. An average of 2.5 fast neutrons carrying 6 Mev. of kinetic energy and 6 Mev. of gamma radiation are released at the moment of fission. The neutrons are slowed down by collisions with atoms of the moderator, and one of them is used up to maintain the fission reaction. The fission fragments subsequently undergo radioactive decay and release beta particles (electrons) with a total kinetic energy of 5 Mev. and gamma rays with an additional energy of 5 Mev. Since the half lives of these fission fragments range from a fraction of a second to many years, emission of this delayed radiation continues after a reactor has been shut down, but at a diminishing rate.

Of these products of the fission process the ones most readily available for research use are fast neutrons, thermal neutrons, and gamma rays. The fission fragments and beta particles are not ordinarily used in a research reactor because of their short range. The energy of these particles is degraded into heat, transferred to the reactor cooling fluid, and wasted.

A typical research reactor, liberating heat at the rate of 1,000 kw, produces 3.7×10^{16} neutrons/sec. in addition to those needed to maintain the fission reaction and those captured by U^{235} to make U^{236}. The fraction of the energy which will appear in the form of gamma radiation is 6 plus 5 Mev. divided by the total energy, 184 Mev., or 6%. Only a fraction of this production of neutrons and gamma radiation can be used in research because of unavoidable absorption in reactor and shield. A 1,000-kw. thermal reactor consumes U^{235} at the rate of 1.35 g./day.

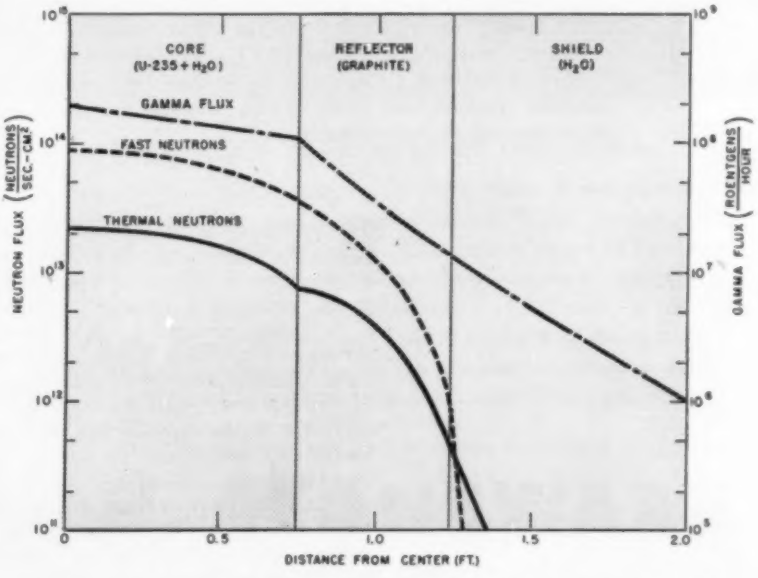


Fig. 3. Typical flux distribution in research reactor (total power = 1,000 kw.).

* 1 kw.-hr. = 2.25×10^{19} Mev.

REACTOR COMPONENTS

The main parts of a research reactor are its core, reflector, and shield. These are illustrated in Figure 2, which is a schematic cutaway view of the proposed Oak Ridge Research Reactor (O.R.R.), one of the most modern of these devices.

In the core, which contains the U^{235} fuel and moderator, the fission reaction takes place and the most intense neutron and gamma radiation is found. A variety of forms of fuel may be used, among which the most common are aqueous solutions of uranyl salts or uranium-metal rods or sheets, the last being used in the O.R.R. The most common moderators are water (used in the O.R.R.), heavy water, and graphite. Cooling for the core may be provided by circulating moderator if liquid (as in the O.R.R.) or by circulating a coolant through separate cooling channels.

The *reflector*, which surrounds the core, is used to reduce the leakage of neutrons from the core and to increase the volume of the reactor containing a useful concentration of neutrons. The reflector is usually made of a material of low molecular weight which scatters neutrons well and absorbs them poorly. In the O.R.R., beryllium is used.

The *shield*, which surrounds the reflector, reduces the intensity of neutron and gamma radiation to below the danger level at the outer face of the reactor. Neutrons or gamma rays to be used outside the reactor are led through beam tubes which penetrate the shield and sometimes the reflector. The best elements for absorbing neutrons are hydrogen, boron, or lithium; whereas the best ones for gamma rays are heavy elements like iron, barium, or lead. It is therefore necessary to use a composite shield. In the reactor mentioned, the inner neutron shield consists of 3 ft. of water, and the outer gamma shield is made of 7 ft. of concrete loaded with barytes aggregate.

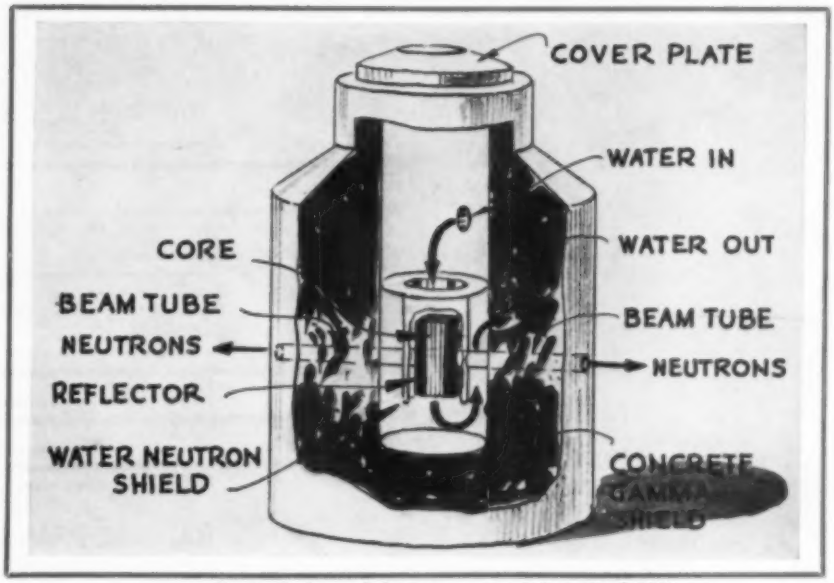


Fig. 2. Tank-type light-water reactor (schematic of ORR).

MEASURES OF RADIATION INTENSITY

The moderator and reflector of an operating reactor contain a veritable blizzard of neutrons rushing in all directions at speeds between 1 and 10,000 miles/sec. To measure the intensity of this hail of neutrons, a concept known as the *neutron flux* has been introduced. This is defined as the product of the average neutron speed and the number of neutrons per unit volume; the neutron flux is numerically equal to twice the number of neutrons crossing a plane surface of unit area from both sides in unit time. The flux is customarily expressed in units of neutrons per square centimeter per second; a powerful reactor has a central flux of 10^{14}.

Gamma radiation intensity is customarily expressed in terms of roentgens per hour, which is the rate of absorption of energy per unit mass of air at the point in question. One roentgen corresponds to absorption of 83 ergs of energy by one gram of air.

The average thermal neutron in the core, θ, is related to the power in kilowatts, P, and the mass of U^{235} in grams, M, by

$$\theta = 2.6 \times 10^{13}\, P/M$$

For example, a reactor with a critical mass of 2,600 g. of U^{235}, operated at a power of 1,000 kw., will have an average thermal neutron flux of 10^{13}. These are representative values for a reactor like the O.R.R. To obtain a high flux, one needs a high power and a low critical mass. The ratio of fast to thermal neutron flux depends on the relative amounts of fuel and moderator.

The average gamma radiation intensity in the core, in roentgens per hour, R', is related approximately to the power and to the core volume, in liters, V, by

$$R' \cong 10^{7}\, P/V$$

For example, a reactor with a core volume of 50 liters operated at a power of 1,000 kw., will have an average gamma flux of 2×10^{8} roentgens/hr.

DISTRIBUTION OF NEUTRON FLUX AND GAMMA-RADIATION INTENSITY IN RESEARCH REACTOR

The variation of neutron and gamma flux within a typical nuclear reactor is shown by the curves of Figure 3. Inside the core gamma flux and neutron flux are relatively uniform, as neutrons and gamma rays are being produced throughout this region. In the reflector, fast neutrons are attenuated most rapidly, because they are slowed down by collisions with the graphite. Thermal neutrons and gamma rays are also attenuated but to a smaller extent. The water neutron shield rapidly wipes out both neutron fluxes but has less effect on the gammas, for which water is a poor absorber.

By adjusting the position of a beam tube in the reactor, it is possible to vary, within limits, the ratios of radiation intensity due to fast neutrons, thermal neutrons, and gamma rays.

To obtain a higher proportion of a single radiation than exists in the reactor at any point, it is necessary to use

some combination of filters and converters. Figure 4 shows some arrangements which have been used.

To produce gamma radiation relatively free from neutrons, a solution of borax in water or a mixture of borax and paraffin is used to slow down fast neutrons and absorb the resultant thermal neutrons while transmitting most of the gamma radiation. To produce relatively clean thermal neutrons, a *thermal column* of graphite, a kind of extended reflector, is used. This converts fast neutrons to thermal neutrons; a bismuth plate then absorbs gammas while transmitting most of the thermal neutrons. Relatively clean fast neutrons are produced by a "converter plate" of natural uranium, which absorbs thermal neutrons and produces fast neutrons from fission of the contained U^{235}.

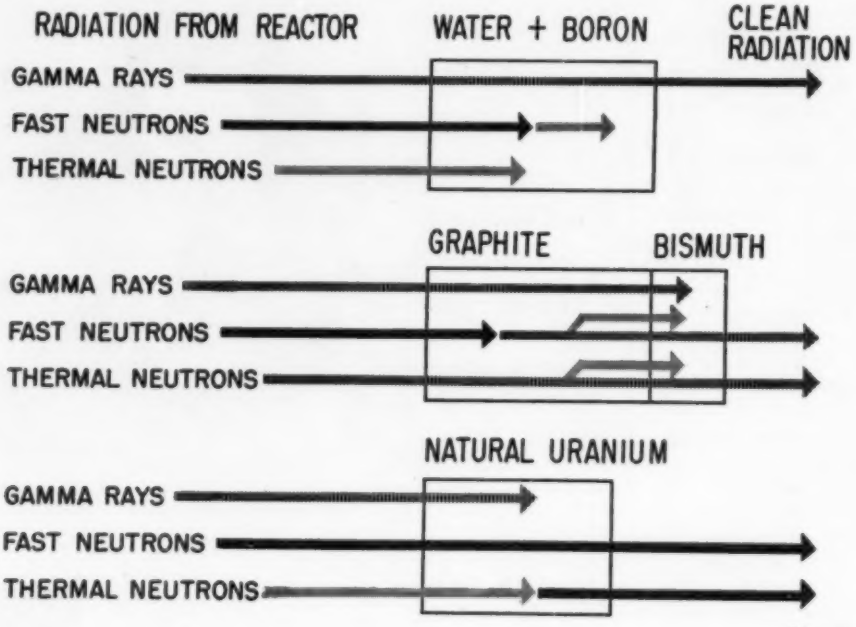


Fig. 4. Means for obtaining clean radiation from reactor.

research uses of nuclear reactors

NEUTRON DIFFRACTION

A reactor is of unique value because it is the most intense source of slow neutrons known. Diffraction of slow neutrons is a powerful new tool for probing the structure of molecules and crystals. Neutrons have wave properties and can be diffracted like X rays. An example (*55*) of these phenomena is afforded by the neutron-diffraction pattern of sodium chloride obtained by the Laue transmission method, shown in Figure 5. The detailed similarity to X-ray–diffraction patterns is apparent. Since slow neutrons do not affect the photographic plate, the diffracted beams are detected by an indium sheet, which is made radioactive, and the gamma radiation emitted by the radioactive indium exposes the photographic plate underneath it.

Scattering of neutrons differs from X rays in two important respects: (1) Neutrons are scattered by light atoms such as hydrogen almost as readily as by heavy atoms; whereas X rays are only weakly scattered by light atoms. (2) Neutrons have a magnetic moment and are scattered selectively by magnetic atoms; whereas X rays are unaffected by them.

To show the advantage of neutrons for locating the position of light atoms, the relative scattering intensities of several elements for X rays and neutrons are shown in Table 1. For X rays the scattering intensity is proportional to the number of orbital electrons; whereas for neutrons it is proportional to the coherent scattering cross sections. The practical importance of this is that neutron diffraction can be used to locate the position of hydrogen atoms in organic molecules such as proteins or plastics, whereas X-ray diffraction cannot. Similarly, neutron diffraction can pin-point the position of hydrogen atoms in crystals, whereas X rays cannot.

Table 1.—Relative Scattering Intensities

	X rays	Neutrons
Proportional to	Number of orbital electrons	Coherent scattering cross section
H	1	1.8
D	1	5.4
C	6	5.4
O	8	4.2
Fe	26	11.4
Pb	82	11.5

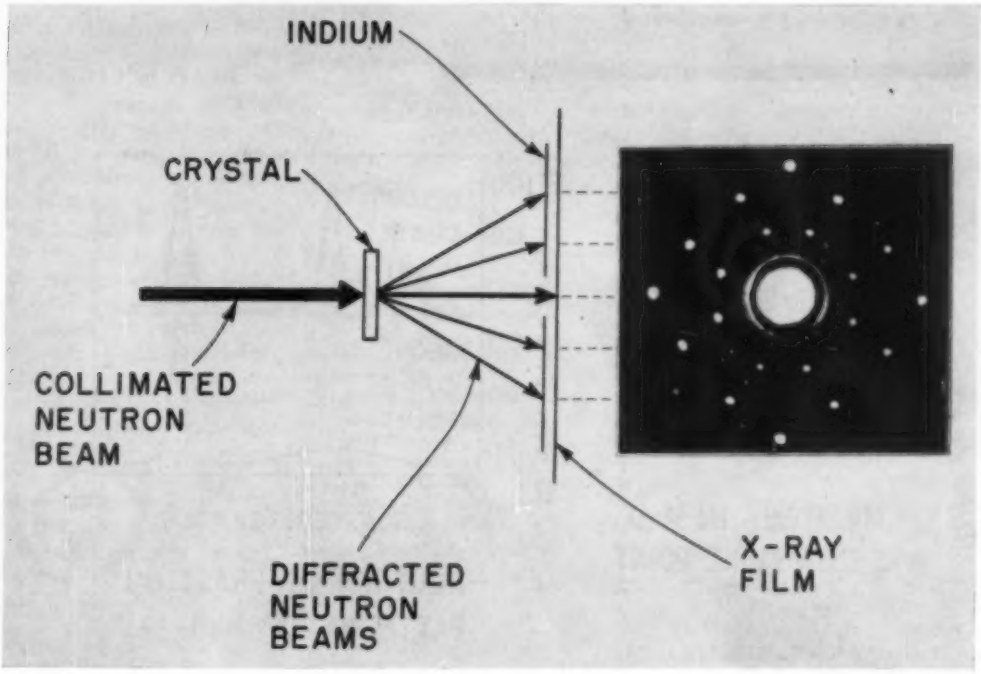


Fig. 5. Laue diffraction of neutrons by sodium chloride (55).

nuclear engineering

An example of the ability of neutrons to resolve the structure of magnetic crystals is afforded by the antiferromagnetic material manganous oxide. Above the Curie temperature of 120° K., crystals are paramagnetic owing to the magnetic moment of the manganous ion. When cooled below the Curie temperature, the crystals lose their paramagnetism. Neutron diffraction shows the reason for this to be that when MnO is cooled below the Curie point, manganous ions in adjacent layers of the crystal have their magnetic moments oriented in opposition, as illustrated by Figure 6, thus canceling any large-scale magnetization. Below the Curie point, atoms in row *B* look different to neutrons than those in rows *C* and *A*, and so the lattice spacing for neutron diffraction is the perpendicular distance from *A* to *C;* the neutron diffraction pattern observed (*48*) is as shown at the top right. Above the Curie point all atoms are randomly oriented, adjacent layers *B* and *C* look the same to neutrons, and the lattice spacing is between adjacent layers. Since the spacing is halved, the scattering angle is doubled, and the neutron diffraction pattern changes to that shown at the bottom right.

This use of neutrons to see the arrangement of magnetic atoms in ferromagnetic and antiferromagnetic crystals is valuable to the electronics industry, which is finding many novel uses for these materials.

A research reactor is also a valuable source of neutron beams for experiments involving the reflection, refraction, or polarization of neutrons.

CROSS-SECTIONAL MEASUREMENTS

A nuclear reactor is an admirable tool for measurement of the specific rate of interaction of slow neutrons with atoms, the so-called neutron "cross sections." The three techniques used for cross-sectional measurement illustrate the three principal ways of using neutrons from a reactor–by a *beam,* by *in-pile experiments,* or by *activation* techniques. In the beam method neutrons streaming from the reactor in parallel paths are passed through a specimen, and the nature, intensity, and angular distribution of radiation scattered by the specimen, or transmitted by it, are measured. In *in-pile* experiments a specimen of the neutron-absorbing material, the cross section of which is to be measured, is placed in the reactor, and its effect on reactivity or flux distribution of the reactor is noted. In the *activation* method a sample is irradiated for a measured time, then it is withdrawn from the reactor, and the amount of radioactivity induced by neutron absorption is measured.

PRODUCTION OF SHORT-LIVED RADIOACTIVE ISOTOPES

Another important use of a reactor for activation is the production of short-lived radioisotopes for research in nuclear physics, chemistry, biology, or medicine. Many long-lived radioisotopes can be purchased from the A.E.C., but ones with half lives under an hour must be produced locally. Nitrogen-16, oxygen-19, and chlorine-38 are examples.

ACTIVATION ANALYSIS

For particular elements activation analysis has proved a more sensitive analytical tool than chemical or spectrographic methods. For example, 1 part per billion of arsenic in substances which are not activated by neutrons can be de-

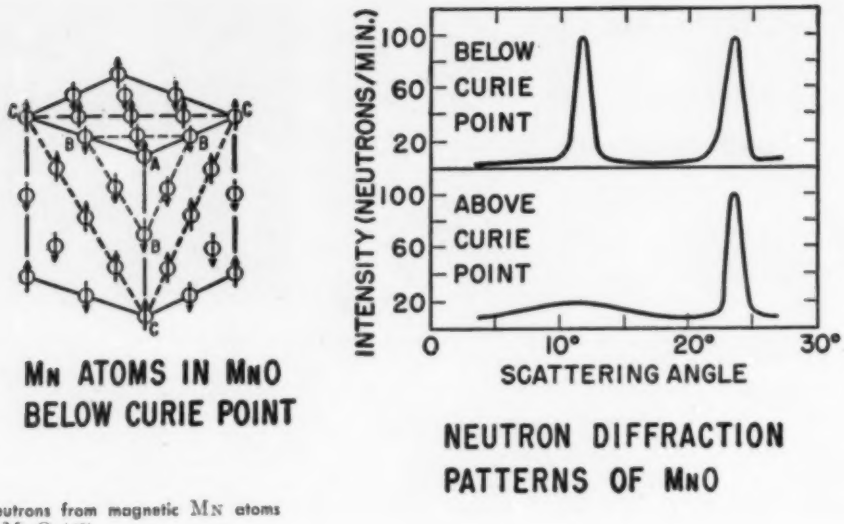


Fig. 6. Scattering of neutrons from magnetic Mn atoms in MnO (48).

tected by irradiating the sample in a reactor and measuring the intensity of gamma radiation characteristic of radioarsenic. Such sensitivity is valuable in analyzing transistor semiconductors for controlled trace impurities or in testing catalysts for poisons.

ACTIVATION OF ENGINEERING TEST MATERIALS

Production of radioisotopes in test specimens is important in various types of engineering research. In studies of friction or wear, one of two surfaces in contact may be made radioactive, and the amount removed by wear may be measured with high precision. This technique has been used to measure the wear rate of piston rings and cutting tools.

Activation in a reactor provides a sensitive means for following diffusion rates in a solid when one component of the solid is made radioactive by neutron irradiation and the second is not.

PROMOTION OF CHEMICAL REACTIONS BY RADIATION

Chemical reactions may be promoted by radiations from a nuclear reactor. Gamma rays and fast neutrons have been shown capable of accelerating many reactions allowed by thermodynamics, and even of inducing reactions which are thermodynamically impossible in the absence of radiation. Yield distributions can be changed by these radiations and new products formed.

Martin and co-workers (*36*) at Michigan and Hayward and Bretton (*29*) at Yale have shown that polyethylene can be produced at lower temperatures and pressures in an intense gamma field than in the usual commercial high-pressure process. Charlesby (*9*), of the British Atomic Energy Research Establishment at Harwell, has shown that irradiation of commercial polyethylene in a reactor induces cross linkages which improve the mechanical properties of the plastic and greatly increase its heat resistance. Charlesby has also shown that rubber can be vulcanized in a reactor and polymethacrylate resins converted to a coherent porous mass with possible heat-insulating properties.

Martin and co-workers (*27*) have shown that the chlorination of hydrocarbons can be catalyzed and modified by gamma radiation, with a different mechanism from that prevailing when the reaction is catalyzed chemically or by ultraviolet light.

These processes can be carried out equally well with any source of high energy radiation, such as electrons from an accelerator, fast neutrons from a reactor, or gamma rays from a reactor or radioactive source. The source selected will depend on its cost and the pentrating power required of the radiation. Electrons from an accelerator penetrate only short distances and hence are most useful for sheet and other materials in thin section. Gamma rays are economical only for materials of substantial thickness. One attractive source of gamma radiation is the shield surrounding a reactor; now this valuable source is wasted by absorption in concrete.

Other radiation-catalyzed reactions which have been suggested or investigated in a preliminary way include production of ethylene glycol from methanol (*38*), production of phenol from benzene and water (*37*), production of hydrazine from ammonia, and synthesis of ammonia at lower temperatures and pressures than in the Haber process. Workers at Harwell have tried to convert graphite to diamond, without reported success, so far!

RADIATION-DAMAGE STUDIES

A related use of high-energy radiation is in studies of radiation damage to solids. High-energy radiation breaks chemical bonds in solids and dislocates ions from equilibrium positions in crystals. An interesting possible application is to the production of controlled dislocations in semiconductors for use in transistors.

TESTING OF REACTOR COMPONENTS

A high-flux research reactor is an indispensable tool for testing the degree of radiation damage experienced by materials and components of power reactors. The Materials-Testing Reactor of the A.E.C. was built primarily for this purpose. Such a reactor can be used to test the degree of burn-up which fuel elements for a power reactor can experience before radiation damage makes proper operation impossible. It can be used to test the effect of prolonged exposure to radiation on metals, gaskets, insulators, and other parts of a reactor which should give long periods of trouble-free service. Another related use is to study corrosion by liquid reactor fuels and coolants under intense reactor irradiation. In order that such tests may be completed in times shorter than the lifetime of a number of years desired for materials to be used in a power reactor, it is important to have the highest possible flux in a reactor for radiation damage studies.

REACTOR-ENGINEERING STUDIES

Other reactor-engineering studies may be conducted in a research reactor with lower flux. These studies include measurement of the nuclear reactivity of fuel elements, measurement of the nuclear properties of proposed reactor lattices, and determination of the effectiveness of different shield materials and configurations.

FOOD PROCESSING

Reactors have many interesting research applications in food processing, biology, and medicine. High-intensity gamma radiation such as may be obtained from a reactor or its spent fuel elements is a potentially attractive means of sterilizing or pasteurizing food or pharmaceutical products. Neutrons cannot be used because they would induce radioactivity in the material being processed. Gamma-radiation doses of about 10^4 roentgens have been shown to improve the storage qualities of meat products (*25*) and potatoes (*49*) and to prevent the reproduction of trichina parasites in pork (*26*) or weevils in grain (*45*). So small a dose has no detectable effect on flavor or appearance. The higher doses needed for complete sterilization, up to several million roentgens, harm flavor. Research on elimination of this difficulty is needed.

Table 2.—Neutron Fluxes Needed for Research Reactor Uses

Radiation damage to metals	10^{14}
Accelerated life tests of power reactor components	10^{14}
Fuel element development	$>10^{13}$
Neutron diffraction	$>10^{13}$
Neutron cancer therapy	$>10^{13}$
Activation of materials	10^{10}–10^{13}
Biological and medical research	$>10^{10}$
Cross-section measurements	$>10^{9}$
Reactor physics	10^{6}

Table 3.—Gamma-Radiation Uses and Sources

Uses	Dose, roentgens	Sources	Flux, roentgens/hr.
		1,000 kw. enriched reactor	
Chemical reactions	10^7–10^8	Core, reactor running	10^8
Sterilization	10^5–4×10^6	Core, 1 day after shutdown	10^7
Food pasteurization	10^5–10^6	Outside neutron shield	2×10^6
Biological research	10^2–10^4	1,000-curie cobalt-60 source	4×10^5
Therapy (local)	10^3–10^4	Van de Graaf generator, 3 Mv., 4ma.	3×10^5

BIOLOGY

Among the valuable topics for biological research with radiation from reactors, one which excites the imagination is acceleration of genetic mutations. Although most radiation-induced mutations are undesirable or recessive or both, some are both desirable and dominant. Treatment with radiation thus opens the possibility of accelerating the development of plants more resistant to disease, molds producing greater yields of antibiotics, and other desirable new forms of life.

MEDICINE

In medicine use of gamma radiation for the treatment of cancer is as old as the discovery of radium; however, valuable new ways of using reactor radiation in cancer therapy are still being developed. One interesting application is neutron therapy with boron-10 (*19, 47*). In this method a solution of boron-10 is injected into the blood, from which it is absorbed selectively at first by cancerous tissue. In the half-hour in which the boron remains selectively in the cancer, the patient is exposed to a beam of thermal neutrons aimed at the cancer. Most of the neutrons are absorbed by the boron in the cancer, with simultaneous production of short-range alpha particles. These are very destructive to the cancerous tissue in which they are formed but do not pentrate adjacent healthy tissue. This makes possible very selective treatment of the cancerous rowth. Because of the short residence time of boron in the cancer, high neutron fluxes must be used.

NEUTRON FLUXES REQUIRED

It will probably have been apparent that different reactor uses require different types of radiation and different fluxes. For reactor uses involving neutrons, Table 2 shows the approximate neutron fluxes needed. The first three uses involve life tests, which should be made at high fluxes if results are to be obtained in acceptable times. Fuel-element tests, for example, require flux times of 10^{21} neutrons/sq.cm.; at a flux of 10^{23} tests would continue for 10^8 sec., or about 3 yr. Neutron diffraction and neutron therapy require beams of neutrons of intensity over 10^9 neutrons/(sq.cm.)(sec.). To obtain such beams, a reactor central flux in excess of 10^{12} is needed. For the other reactor uses, more modest fluxes suffice.

GAMMA USES AND SOURCES

In the case of gamma radiation, the total radiation dosage is more significant than the flux. The left column of Table 3 gives the total gamma dose, in roentgens, required for different gamma uses. The right column gives the gamma flux, in roentgens per hour, available from various gamma sources. In the core of a 1,000-kw. reactor the gamma flux is high enough to complete chemical reactions in less than 1 hr. The flux outside the neutron shield in such a reactor is high enough for food sterilization in 1 hr. and food pasteurization in a few minutes. This reactor, even after shutdown, is a more intense source of gamma radiation than is a 1,000-Curie cobalt-60 source or a Van de Graaf generator. The generator, however, produces very intense radiation in the form of electrons.

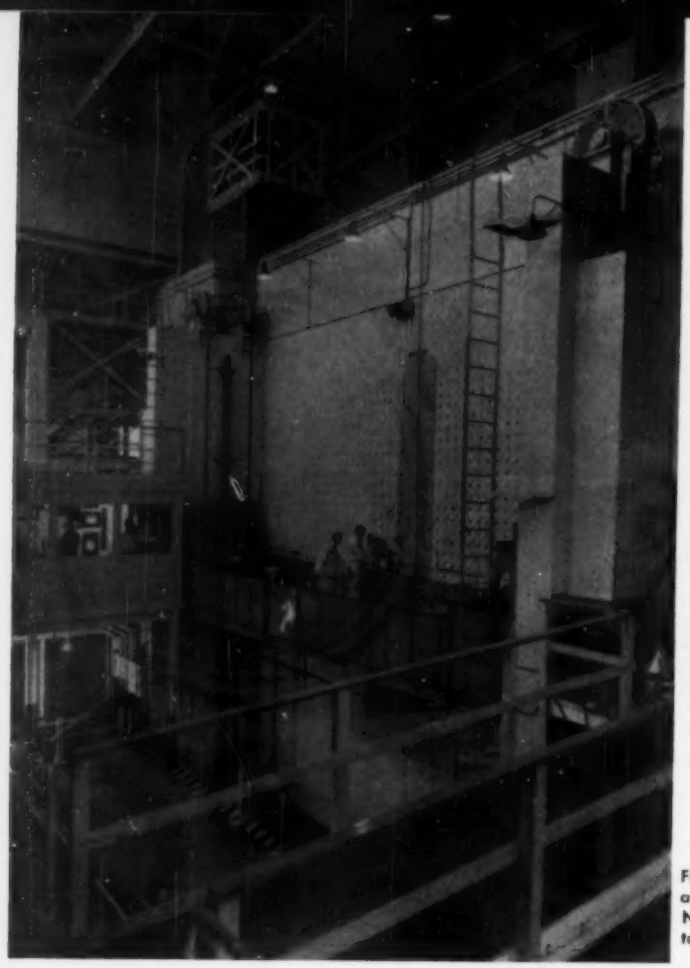


Fig. 7. X-10 Reactor, Oak Ridge National Laboratory.

types of research reactors

The principal types of research reactors are natural-uranium reactors moderated by graphite, natural-uranium reactors moderated by heavy water, enriched-uranium fluid-fuel reactors, and enriched-uranium solid-fuel reactors. Each type will be discussed briefly.

NATURAL-URANIUM–GRAPHITE REACTORS

The first research reactors used natural uranium as fuel and graphite as moderator, because isotope-separation plants to make U^{235} or heavy water were not available. Table 4 lists the six research reactors of this type which have been described. CP-1 is the famous Chicago Pile Number 1, in which self-sustaining nuclear fission was first demonstrated. The last four of these piles are still operating.

Figure 7 is a photograph of the X-10 reactor at Oak Ridge. It is a large structure with a cubic core 25 ft. on a side, containing about 35 tons of uranium-metal rods and 500 tons of graphite. Cooling is provided by air passing through annular spaces between uranium and graphite. The other reactors of this type are roughly similar in mechanical construction, the principal difference being in the power and flux at which they operate and in the volume of cooling air required.

These reactors as a group are characterized by their large size and high cost and the high power needed for a useful flux. These all are consequences of the large critical mass when natural uranium is used as fuel and graphite as moderator. It is unlikely that more research reactors of this type will be built.

NATURAL-URANIUM–HEAVY-WATER REACTORS

Reactor designers have taken advantage of the fact that the size and critical mass of natural-uranium reactors can be substantially reduced when the better moderator, heavy water, is substituted for graphite. Table 5 lists the seven reactors of this type which have been built or projected. The amount of uranium in these reactors is reduced to less than 10 tons, the reactor core dimensions are down to 6 to 8 ft., fluxes are higher, and the cost for a given flux is lower.

The NRX reactor at Chalk River has probably done more useful work than any other single research reactor, and its flux is second only to the Materials-Testing Reactor. It is in operation again after its 1952 accident, at the increased flux of 6.7×10^{13}.

All these reactors except CP-3 are

Table 4.—Natural-Uranium—Graphite Reactors

Reactor	Location	Date	Mass, kgm. U	Mass, kgm. U^{235}	Power, kw.	Maximum thermal flux	Cost, $ million	References
CP—1	Chicago	1942	37,000	260	0.2	.....	...	(16, 10, 39)
CP—2	Chicago	1943	42,500	300	2.0	.....	...	(35)
X—10	Oak Ridge	1943	32,000	230	3,800	5×10^{11}	5.2	(35)
GIEEP	Harwell	1947	28,000	200	100	3×10^{10}	...	(14, 17, 18)
BEPO	Harwell	1948	36,000	260	4,000	10^{12}	...	(1, 43)
BNL	Brookhaven	1950	54,000	385	28,000	4×10^{12}	20	(11, 4, 35)

Typical core dimensions: 25-ft. cube
Typical weight graphite: 500 tons

located abroad. This is primarily a result of the nonavailability of enriched uranium in foreign countries until President Eisenhower's recent offer. Enriched uranium makes possible a further reduction in reactor size and cost.

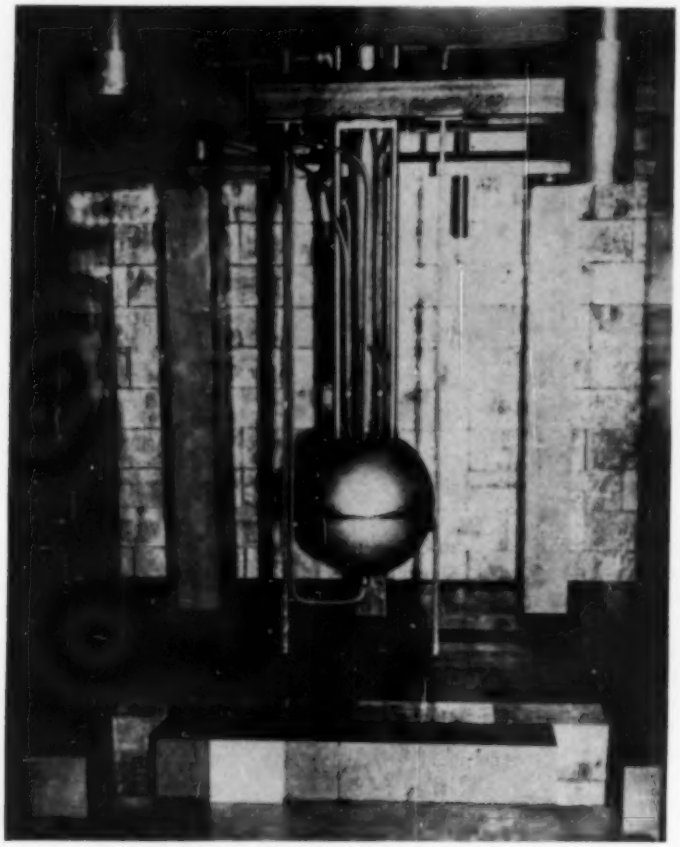


Fig. 8. Core-tank of Los Alamos SUPO water-boiler reactor, Los Alamos Scientific Laboratory.

WATER-BOILER REACTORS

Reactors using an aqueous solution of enriched uranyl salt as fuel have come to be known as "water-boiler" reactors, even though the solution does not boil. The name was given at Los Alamos, where the first of these reactors was built. Figure 8 is a photograph of the most recent water-boiler reactor built at Los Alamos (named SUPO) while under construction. The core consists of a spherical vessel only 1 ft. in diam. containing a solution of 800 g. of U^{235} in the form of uranyl nitrate, dissolved in ordinary water. Cooling is provided by water circulated through a coil wound inside the sphere. The core is surrounded by a thick graphite reflector, part of which is seen behind the core in the photograph. This reactor develops an average thermal flux of 10^{12} at a power of only 30 kw., a combination possible because of the low critical mass of U^{235}. For comparison, critical masses of U^{235} in natural-uranium reactors were around 20 kg. with heavy water and over 200 kg. with graphite.

Table 5 lists the water-boiler reactors which have been described in the open literature. All use the Los Alamos design, and differ primarily in the power and flux at which they have been operated. The reactor at North Carolina State College is notable as being the first university research reactor in the world. The cost of this reactor and

Table 5.—Natural-Uranium–Heavy-Water Reactors

Reactor	Location	Date	Mass, kgm. U	Mass, kgm. U^{235}	Power, kw.	Maximum thermal flux	Cost, $ million	References
CP–3	Chicago	1944	2,700	19.5	300	.....	2	(12, 10, 39)
NRX	Chalk River	1947	9,500	68	40,000	6.7×10^{13}	10	(8, 21, 28)
Zoé	Chatillon, France	1948	3,150	23	10	3×10^{10}	..	(32, 40, 42, 56)
JEEP	Norway	1951	2,200	16	250	3×10^{11}	2.2	(15)
Cyrano	Saclay, France	1952	3,000	21	1,500	6×10^{12}	..	(34, 44, 24)
SLEEP	Stockholm	1954	3,000	21	300	3×10^{11}	..	(16, 21, 44)
.....	Switzerland	Future	5,000	36	10,000	2×10^{13}	5	(24, 44)

Typical core dimensions: 6 ft. diam. × 8 ft. high.
Typical weight, D_2O: 7 tons.

Table 6.—Water-Boiler Reactors

Reactor	Location	Date	Form	U^{235} Kg.	Power, kw.	Average thermal flux	Cost, $ million	References
LOPO	Los Alamos	1944	UO_2SO_4	0.6	5×10^{-3}	2×10^{6}	.....	(46)
HYPO	Los Alamos	1944	$UO_2(NO_3)_2$	0.8	6	3×10^{11}	.....	(12, 10, 39, 46)
SUPO	Los Alamos	1951	$UO_2(NO_3)_2$	0.8	30	10^{12}	.....	(32)
North American Aviation	Downey, Calif.	1951	$UO_2(NO_3)_2$	0.7	0.002	10^{6}	0.075	(13, 50)
North Carolina State College	Raleigh, N. C.	1953	UO_2SO_4	0.8	20	4×10^{11}	0.5	(2, 3)

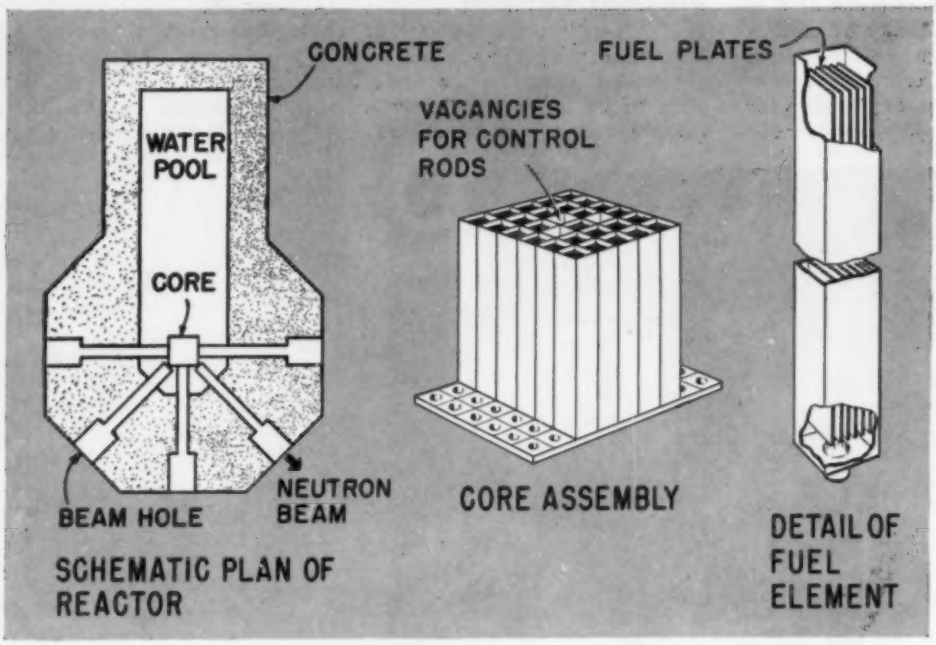


Fig. 9. Swimming pool reactor.

building was $500,000, of which only $120,000 was for the reactor.

The power of this type of reactor is limited to about 30 kw., or 2.5 kw./liter of core volume, because of decomposition of the solution by fission fragments. Water is dissociated into hydrogen and oxygen at a rate of 17 liters per kw.-hr., and the uranium solution tends to become unstable at higher power densities. Unless the reactor is operated under pressure, the high volumetric rate of gas production gives rise to difficulties both from expansion of the liquid by gas bubbles and from entrainment of liquid in the gas. A system to circulate and recombine the hydrogen and oxygen must be provided. Because of the intense radioactivity of the solution and gases (which contain gaseous fission products), the reactor plumbing must be absolutely leak tight. These drawbacks to the water boiler will probably limit its use to low-power installations of the type already developed. For fluxes obtainable at these powers, its small size and comparatively low cost make it an attractive research tool.

A water-boiler reactor using heavy water as solvent and reflector could develop a flux of 10^{13} without exceeding the SUPO power density of 2.5 kw./liter. This is a possible way of increasing the flux of a water boiler. The reactor would operate at a power of about 300 kw. and would produce about 5,000 liters of mixed deuterium and oxygen gas/hr., which would have to be recombined. This does not sound very attractive when compared with the solid-fuel reactors capable of developing this flux.

ENRICHED-URANIUM–SOLID-FUEL REACTORS

As shown in Table 7, nine reactors using enriched uranium in solid fuel elements have been built or projected in this country. Judged from the high fluxes attainable and the low cost per unit of flux, this type of reactor is the most successful research reactor yet developed. The Materials-Testing Reactor has the highest thermal flux of any reactor in the world; at some points in the reflector, values of 4.5×10^{14} are obtained.

All these reactors use the type of fuel element developed by the Oak Ridge National Laboratory for the MTR. Two variants of these solid-fuel reactors have been developed, the "swimming-pool" type, in which the fuel elements are set in an open pool of

Table 7.—Solid-Fuel–Enriched Reactors

Reactor	Location	Date	Moderator	U^{235}, kg.	Power, kw.	Average thermal flux	Cost, $ million	References
			Swimming-pool Type					
BSF	Oak Ridge	1951	H_2O	2.5	100	10^{12}	0.25	(6)
	Pennsylvania State University	1955	H_2O	2.5	100	10^{12}	0.3	(7, 5)
	University of Micigan	1956	H_2O	3	1,000	10^{13}	1.0	(54)
			Closed-tank type					
LITR	Oak Ridge	1950	H_2O	3	2,000	2×10^{13}	1	(6)
MTR	Idaho	1952	H_2O	4	30,000	2×10^{14}	18	(30)
NTR	West Schenectady	1952	$H_2O + C$	2.5	30	3×10^{11}	.....	(20, 51)
CP-5	Argonne	1954	D_2O	1.7	1,000	1.5×10^{13}	2.3	(52, 53)
Omega	Los Alamos	1955	H_2O	3	1–4,000	$1\text{-}4 \times 10^{12}$	.....	
ORR	Oak Ridge	1956	H_2O	3.3	10,000	7×10^{13}	2.8	(22, 23)

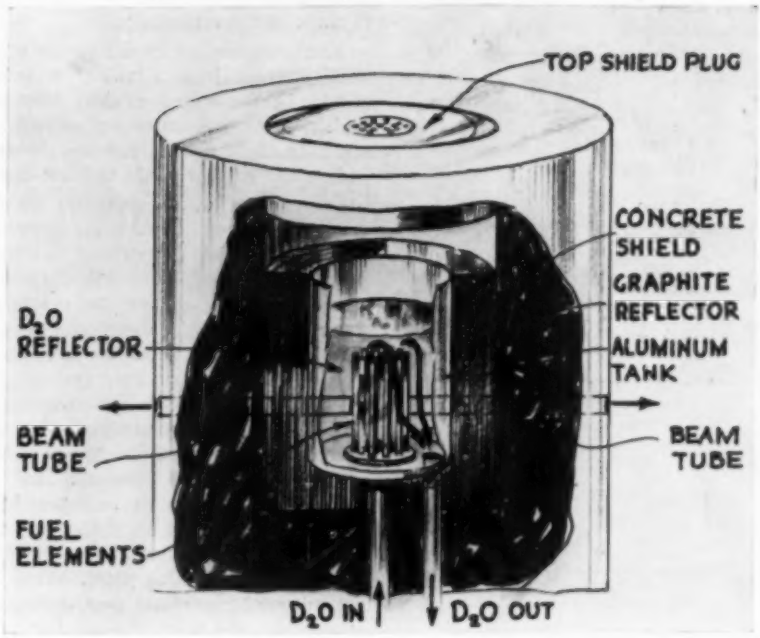


Fig. 11. Tank-type heavy-water reactor (schematic of Argonne CP-5).

water, and a second type in which they are set in a closed tank.

Figure 9 is a schematic drawing of the swimming-pool type. Each fuel element consists of a stack of eighteen fuel plates 0.060 in. thick spaced about 0.1 in. apart and held in a square box 3 in. on a side. Water flows through the box and provides cooling and moderation. Each fuel plate consists of an inner layer of an alloy of U^{235} and aluminum sandwiched between outer layers of pure aluminum, which protect the uranium from attack by water and keep fission products out of the water.

The reactor-core assembly consists of from twenty-four to thirty of these fuel elements set in a rectangular array. Core dimensions are about 12 by 18 by 24 in. In the swimming pool reactor the core assembly is mounted under 20 ft. of water in an open pool. The walls of the pool are concrete, through which neutron-beam tubes are led. At powers up to 300 kw., convective circulation of water in the pool provides adequate cooling of the core. At higher powers forced circulation by a pump is desirable to prevent boiling and to draw away from the surface of the pool, water containing high nitrogen-16 activity resulting from neutron irradiation.

One big attraction of the swimming-pool reactor is its low cost, due to simple construction. Another is its flexibility, since the reactor core can be moved or rebuilt with a minimum of difficulty. The large volume of water in the pool with relatively high gamma flux and low neutron background make it useful for bulk gamma irradiation experiments.

The tank-type of solid-fuel reactor, shown in Figure 2, differs from the swimming pool in having a closed tank, less water, more concrete shielding, an immovable core, and, in most models, a thicker reflector. All these changes make for greater reactor safety and are practically essential at fluxes above 10^{13}.

The most advanced research reactor now in operation is the CP-5 reactor of the Argonne National Laboratory. This reactor is of the closed-tank type, but it uses heavy water instead of light water as moderator and coolant. Figure 10 is a photograph and Figure 11 a schematic section of the reactor. Fuel elements are of the MTR type, but have fewer plates per element. Because of the superior moderating properties of heavy water compared with light water, twelve elements suffice to make this reactor critical. The core, roughly 2 ft. in diam. and 2 ft. high, is surrounded by 2 ft. of heavy-water reflector and 2 ft. of graphite reflector. These reflectors provide a much larger volume at high and relatively uniform flux than do those in the light-water reactors. A heavy-water reactor needs only half the power of a light-water reactor developing the same flux, because the critical mass of the heavy-water reactor is only about half that of a light-water reactor.

In addition to these advantages of the heavy-water reactor, it is a very safe reactor, because its neutron lifetime is about sixteen times as great as that of the swimming-pool reactor. This is another consequence of the low critical mass and large volume of core and reflector, which give neutrons more time to travel about before they leak out or are captured. Because of the long neutron lifetime, the reactor responds much more slowly to reactivity changes and is much less likely to stage a nuclear runaway.

These advantages of the heavy-water reactor are not gained cheaply. The reactor needs 7.5 tons of heavy water, worth close to $1 million. This is not included in the tabulated cost of $2.3 million. To guard against loss or contamination of the water, the reactor core is made less accessible than in a swimming pool, and so the reactor is less flexible. Because of plumbing complications introduced by the heavy water, the reactor costs more than a tank-type light-water reactor of the same power. When costs are compared at the same flux, however, the heavy-water reactor is at less of a disadvantage.

nuclear engineering

RESEARCH-REACTOR COSTS

Table 8 compares the cost of these different types of enriched research reactors at fluxes of 10^{12}, 10^{13}, and 10^{14}. The costs of this table are for reactors only; costs cited in previous tables have included the building, and differences in building specifications and costs may have obscured comparisons among reactor costs. The costs given in this table at a flux of 10^{14} are the author's own guesses based on information available for these reactor types at lower fluxes. At a flux of 10^{12} the water boiler and swimming pool are cheaper than the tank type of reactor. At a flux of 10^{13} the water boiler is impractical, the swimming pool is the cheapest type, and the heavy-water reactor is the most expensive. At a flux of 10^{14} the only practical reactors are the tank types; the heavy-water reactor may be somewhat cheaper than the light-water reactor because its power is lower by 6,000 kw. This lower cost is not realizable, however, unless the heavy water can be borrowed from the A.E.C. without charge, as is now possible for U^{235}.

Table 8.—Enriched Reactor Costs

Average thermal flux	10^{12}	10^{13}	10^{14}
Water boiler			
Power, kw.	30	Impractical	
Cost	$120,000		
Swimming pool			
Power, kw.	100	1,000	Impractical
Cost	$100,000	$400,000	
Tank type, light water			
Power, kw.	100	1,000	14,000
Cost	$200,000	$600,000	$2,000,000
Tank type, heavy water			
Power, kw.	.....	600	8,000
Cost	.....	$800,000	$1,800,000

Note:—Costs are for reactors only, without charges for U^{235}, D_2O, building, or experimental equipment.

safety aspects of research reactors

HAZARDS OF NUCLEAR REACTORS

No discussion of research reactors is complete without mention of their safety problems. The greatest hazard of research reactors is accidental escape of fission products from the fuel. Fission products are extremely poisonous because of their intense radioactivity, and all possible precautions must be taken to keep them inside the reactor. Fortunately, a thermal research reactor cannot explode like an atomic bomb, because it cannot liberate energy rapidly enough.

Table 9 gives some indication of the toxicity of fission-product poisons in a 1-Mev. reactor in steady operation. If the reactor contents were to escape from behind the shield and form a small cloud, a man 10 meters from the center of the cloud would receive 400 roentgens/min. of gamma radiation. Since the lethal dose (one which kills 50% of the people exposed to it) is 400 roentgens, this man would have only 1 min. to get away.

Of the individual fission products, iodine-131 and strontium-89 are two of the most toxic if breathed or swallowed. The 27,000 curies of iodine-131 present in a 1-Mw. reactor represents 100 million lethal doses. The 40,000 curies of strontium-89 represents 8 million lethal doses. In respect to the amount of poison held in the reactor, even a small research reactor is as serious a hazard as a large chemical plant.

PREVENTION OF ESCAPE OF FISSION PRODUCTS

In a swimming-pool reactor, failure of fuel-element cladding by corrosion or radiation damage could release fission products into the pool water and air. In a water boiler like SUPO, leakage of the plumbing could cause serious radioactive contamination of the surroundings of the reactor. Each of these reactors has only one line of defense against fission-product leakage; on the other hand, the tank type of reactor has two seals against fission-product leakage—the cladding and the reactor tank—and hence cannot leak fission products as a result of corrosion or tank failure if these occur separately.

The most likely way for fission products to escape from a tank-type reactor would be through a nuclear runaway which would release enough energy to melt the cladding and rupture the tank before the reactor could be shut down.

Fortunately all the reactors considered here have self-stabilizing characteristics which in all but the most extreme cases will automatically terminate a runaway before the reactor is damaged. In the water boiler an increase in power causes an increase in the volume of hydrogen and oxygen bubbles; this allows more neutrons to leak from the core and shuts down the reactor when the bubble volume becomes great enough. In the solid-fuel reactors, a rapid increase in power heats the fuel, and after a short time lag this heat is transferred to the water, which is raised to its boiling point. When the steam formed increases neutron leakage sufficiently, the reactor shuts down.

COURSE OF NUCLEAR RUNAWAY

In any nuclear runaway the important question is whether enough gas can form to shut the reactor down before so much energy is released that the reactor is damaged. A rough answer to this question is that the reactor will shut itself down without damage if the period in which the reactor power increases by a factor of e is longer than the time lag for heat transfer. A slow increase in power is safe; too rapid an increase may be dangerous.

In a water boiler there is practically no time lag for gas formation after power increase, and so these reactors will shut themselves down safely if enough free volume is provided for

Table 9.—Hazards from Fission-Product Poisons in 1-Mw. Reactor

Irradiation by Gamma Rays

Reactors contents	400 roentgen/min. at 10 m.
Tolerance dose rate	0.0075 roentgen/hr.
Lethal dose	~400 roentgens
Time to receive lethal dose at 10 m.	1 min.

Ingestion of	Iodine—131	Strontium—89
Reactor contents, curies	27,000	40,000
Tolerance dose, curies *	0.0000003	0.000008
Approximate lethal dose, curies	0.0003	0.005
Number of lethal doses in reactor	10^8	8×10^6

* The tolerance and lethal doses of this table have been obtained from data in (41).

expansion of the solution. On the other hand, in solid-fuel reactors using M.T.R. fuel elements there is a time lag of some 7 msec. for transfer of heat from the U^{235} in the center of the fuel plate to the adjacent water. The reactor period should be longer than this for a solid-fuel reactor to be safe in a nuclear runaway.

The period for an exponential increase in power in a nuclear runaway, π, is given by

$$\pi = \frac{\tau}{\delta - 0.0075}$$

where

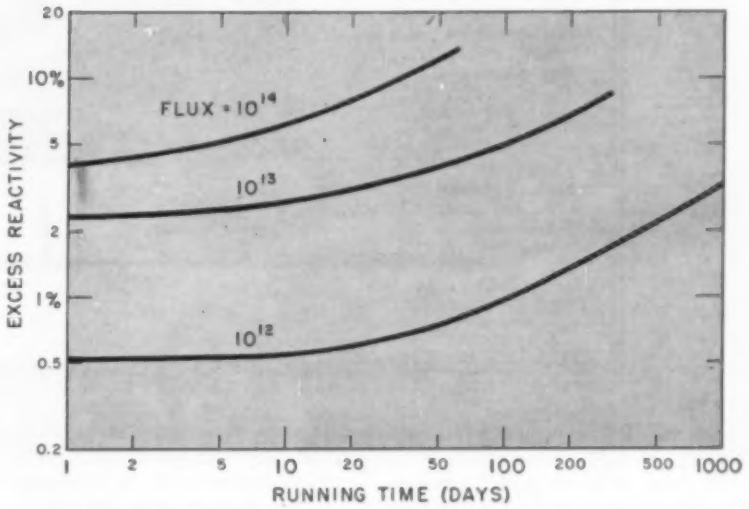
τ is the mean neutron lifetime
δ is the excess reactivity, defined as the difference between the neutron production and consumption rates divided by the production rate
0.0075 is the fraction of the neutrons produced in fission which are delayed long enough to be without effect in a rapid nuclear runaway.

The period of the exponential rise of power will therefore be long if the mean neutron lifetime is long and the excess reactivity is kept low.

The calculated mean neutron lifetime for a light-water reactor like the swimming pool is 0.06 msec.; for a heavy-water reactor like CP-5, it is 1 msec. The excess reactivity which will cause a period of 7 msec. in a swimming-pool reactor is 1.9%; in a heavy-water reactor it is over 10%.

Good practice dictates that the amount of excess reactivity loaded into a reactor by fuel addition or control-rod withdrawal be kept to an absolute minimum. Nevertheless, substantial amounts of excess reactivity must be available in reserve to compensate for long-term growth of fission-product poisons and burn-up of fuel. Figure 12 shows how much excess reactivity is needed for these purposes as a function of the time a fuel charge is left in the reactor for fluxes of 10^{12}, 10^{13} and 10^{14}. The amount shown in 1 day is needed to compensate for xenon-135, a fission-product neutron absorber which soon reaches a steady concentration; the gradual increase after 1 day is due to other fission products and burn-up of fuel. For a flux of 10^{13} and a reasonable fuel life, an excess reactivity of 4 to 5% is needed. With further allowances for temperature changes and consumption of neutrons in experiments, reserve excess reactviity in the range of 6 to 8% is desirable.

With this much excess reactivity in reserve, there is a remote possibility that it might be added suddenly to the reactor by accident and lead to nuclear runaway. A heavy-water reactor like CP-5 subjected to this runaway would shut itself down without damage; a light-water reactor like the swimming pool would be damaged and would spread fission-product poisons. The remarkable stability and safety of a heavy-water reactor are due to the long lifetime of neutrons in heavy water. For maximum safety, no other reactor can equal one using heavy water as moderator and reflector.



EXCESS REACTIVITY NEEDED FOR FUEL DEPLETION AND FISSION PRODUCT GROWTH

Fig. 12. Excess reactivity needed for fuel depletion and fission product growth.

comparison of research reactors

Research reactors which use natural uranium as fuel are much bigger and cost more than those using enriched uranium producing the same flux. So long as enriched uranium is available, it will be the preferred fuel for new research reactors.

The various types of research reactors using enriched uranium are compared in Table 10. At the bottom of this table the reactors are ranked with respect to safety, cost, and versatility.

With respect to safety, the heavy-water, tank-type reactor is rated first, because of its long neutron lifetime, the high excess reactivity which can be used in it with safety, and the presence of two seals against fission-product leakage. The light-water, tank-type reactor, with graphite reflector, is rated second in safety, because it also has two seals against fission-product leakage and has a neutron lifetime and maximum safe reactivity greater than the swimming pool. The water boilers are rated less safe because of the disagreeable consequences of leakage. The swimming pool is considered least safe because of the open pool and the short neutron lifetime.

At a flux of 10^{12}, where safety is a less vital factor, the swimming pool and water boiler cost least and would be preferred. At a flux of 10^{13} the swimming pool costs least, the light-water tank type costs more, and the heavy-water reactors are most expensive. The H_2O water boiler is impra-

Table 10.—Comparison of Enriched Research Reactors

Type	Water Boiler		Swimming Pool	Tank Type	
Moderator	H_2O	D_2O	H_2O	H_2O	D_2O
Reflector	Graphite	D_2O	H_2O	Graphite	D_2O
Neutron lifetime, msec.	0.16	1	0.06	0.2	1
No. of seals for fission products	1	1	1	2	2
Max. practical flux	10^{13}	10^{13}	$\sim 10^{13}$	$>10^{14}$	$>10^{14}$
Kg. U^{235}	0.8	0.8	3	3	1.7
Cost,* flux $= 10^{13}$	$120,000	?	$100,000		
10^{10}	.....	?	400,000	$600,000	$800,000
10^{14}	.....	.....	.....	2,000,000	1,800,000
Rank (1 = best)					
Relative safety	4	3	5	2	1
Economy ($\phi = 10^{13}$)	.....	4?	1	2	3
Versatility	3	3	1	2	3

* Reactor only.

tical because of excessive gas formation.

At a flux of 10^{14} it is undesirable to use the open swimming-pool reactor. The tank-type heavy-water reactor may have a slight cost advantage at this flux if heavy water can be obtained from the A.E.C. without charge.

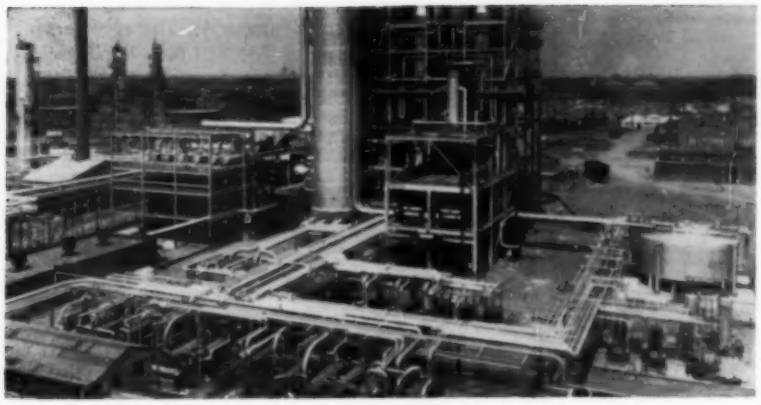
With respect to versatility, the swimming pool is rated first, because of the ease with which the reactor core can be rearranged and experiments set up in the core and water shield. This is truly an "erector set" reactor. The light-water, tank-type reactor is rated next, because rearrangements within the water tank are possible, though the heavy graphite reflector, the immobility of the core, and the tank closure make changes difficult. The heavy-water reactor and the water boilers are least flexible because of the difficulty of opening the reactor piping for changes.

The reactor to be chosen for a particular laboratory will depend on the flux required and on the relative importance attached to the factors of safety, economy, and versatility. All these reactors are valuable research tools under the proper circumstances, and they will undoubtedly come into widespread use in this country and abroad.

Literature Cited

1. Atomics, **2**, 176 (1951).
2. Beck, C., et al., *N. Carolina State Coll. Report*, NSCS-46 (1952).
3. Beck, C., Private communication (1954).
4. Borst, L. B., *Physics Today*, **4**, 6 (1951).
5. Breazeale, W. M., *Chem. Eng. Progr., Symposium Ser. No. 12*, **50**, 6 (1954).
6. Breazeale, W. M., *Nucleonics*, **10** (11), 56 (1952).
7. *Ibid.*, **12** (2), 73 (1954).
8. *Can. Chem. Processing*, **35**, 40 (1951).
9. Charlesby, A., *Nature*, **171**, 167 (1953); *Nucleonics*, **12** (6), 18 (1954); *Proc. Roy. Soc. (London)*, **A215**, 187 (1952).
10. *Chem. Eng.*, **58** (1), 113 (1951).
11. *Ibid.* (5), 271 (1951).
12. *Chem. Eng. News*, **28**, 4254 (1950).
13. *Ibid.*, **30**, 3506, 3642 (1952).
14. Colmer, F. C. W., and D. J. Littler, *Nucleonics*, **8** (1), 3 (1951).
15. Dahl, O., and G. Randers, *Nucleonics*, **9** (11), 5 (1951).
16. Eklund, Sigvard, *Chem. Eng. Progr. Symposium Series* No. 11, **50**, 189 (1954).
17. *Engineering*, **170**, 497 (1950).
18. *Engineering*, **171**, 464 (1951).
19. Farr, L. E., W. H. Sweet, et al., *Am. J. Roentgenol.*, **71** (2), 279 (1954).
20. General Elec. Co., *Pamphlet R54A0511*.
21. Gilbert, F. W., *Nucleonics*, **10** (1), 6 (1952).
22. Gill, J. P., *Chem. Eng. Progr. Symposium Series* No. 12, **50**, 43 (1954).
23. Gill, J. P., *Nucleonics*, **12** (9), 37 (1954).
24. Goedkoop, J. A., *Nucleonics*, **11** (12), 10 (1953).
25. Goldblith, S. A., B. E. Proctor, S. Davison, B. Kan, C. J. Bates, E. M. Oberle, M. Karel, and D. A. Lang, *Food Research*, **18**, 659 (1953).
26. Gomberg, H. J., S. E. Gould, J. V. Nehemias, and L. E. Brownell, *Chem. Eng. Progr. Symposium Series* No. 13, **50**, 89 (1954).
27. Harmer, D. E., L. C. Anderson, and J. J. Martin, *Chem. Eng. Progr. Symposium Series* No. 11, **50**, 253 (1954).
28. Hatfield, G. W., Private communication (1954).
29. Hayward, J. C., and R. H. Bretton, *Chem. Eng. Progr. Symposium Series* No. 13, **50**, 73 (1954).
30. Huffman, J. R., *Nucleonics*, **12** (4), 21 (1954).
31. Isbin, H. S., *Nucleonics*, **10** (3), 10 (1952).
32. King, L. D. P., Los Alamos Scientific Lab. Rept. 1301 (1952).
33. Kowarski, L., *J. phys. radiums*, **12** (7), 151 (1951).
34. Kowarski, L., *Nucleonics*, **12** (8), 8 (1954).
35. Lane, J. A., *Nucleonics*, **12** (4), 12 (1954).
36. Lewis, J. G., J. J. Martin, and L. C. Anderson, *Chem. Eng. Progr.*, **50**, 249 (1954).
37. Manowitz, B., *Chem. Eng. Progr. Symposium Series* No. 12, **50**, 20 (1954).
38. McDonnel, W. R., Univ. Calif. Rad. Lab. Rept. 1378.
39. *Mech. Eng.*, **73**, 142 (1951).
40. *Metal Progr.*, **56** (9), 202 (1949).
41. *Natl. Bur. Standards (U.S.), Handbook 52* (1953).
42. *NP-2038*.
43. *Nucleonics*, **8** (6), 36 (1951).
44. *Oak Ridge Natl. Lab. Rept.* 114 (1953).
45. Proctor, B. E., E. E. Lockhart, and S. A. Goldblith, *Food Technol.* (in press).
46. *Rev. Sci. Instr.*, **22** (7), 489 (1951).
47. Shoup, C. S., AECU-2900, 135 (1954).
48. Shull, C. G., W. Strauser, and E. O. Wollan, *Phys. Rev.*, **83**, 333 (1951).
49. Sparrow, A. H., and E. Christensen, *Nucleonics*, **12** (8), 16 (1954).
50. Starr, C., Private communication (1954).
51. Stewart, H., F. La Violette, C. McClelland, G. Gavan, and T. Snyder, *Nucleonics*, **11** (5), 39 (1953).
52. Untermeyer, S., *Nucleonics*, **12** (1), 12 (1954).
53. Weills, J. T., *Chem. Eng. Progr. Symposium Series* No. 11, **50**, 213 (1954).
54. Widdoes, L. C., *Chem. Eng. Progr. Symposium Series* No. 11, **50**, 195 (1954).
55. Wollan, E. O., C. G. Shull, and M. C. Marney, *Phys. Rev.*, **71**, 666 (1947).
56. Zucker, A., *Physics Today*, **4** (1), 12 (1951).

Presented at A.I.Ch.E. forty-seventh annual meeting, New York, December 12-15, 1954.



solving conductive heat transfer problems with electrical-analogue shape factors

Robert V. Andrews

Texas Engineering Experiment Station,
Texas A. & M. College System,
College Station, Texas.

Only a few very simple geometric shapes, such as the flat plate, the cylinder, and the sphere, can be used easily for the analytical calculation of conductive heat transfer problems (1). Other simple shapes, as well as more complicated geometric configurations, require such complicated boundary conditions for the calculation of heat transfer by conduction through them, that an exact solution is impossible or impractical to obtain. However, by the use of Langmuir's shape factor (S. F.) to replace the geometrical terms in Fourier's equation for conductive heat transfer, the solution of such problems becomes an easy matter (2). The purpose of this study is to present shape factors for a number of configurations which can be used to solve practical heat transfer problems and to present a simple, inexpensive, electrical analogue method of determining shape factors for any geometric configuration which can be expressed in three dimensions, one of which is unit length.

Ohm's law of electrical conduction states

$$i = -k_e(A/b)(\Delta e) = \Delta e/R_e \qquad (1)$$

and Fourier's law of heat conduction states

$$q = -k(A/b)(\Delta t) = \Delta t/R \qquad (2)$$

where

i = electrical current time rate, amp.
k_e = electrical conductivity, mhos
Δ_e = electrical potential difference, v.
R_e = electrical resistance, ohms
q = heat quantity time rate, B.t.u./hr.
k = thermal conductivity, B.t.u./(hr.)(sq.ft.)(°F./ft.)

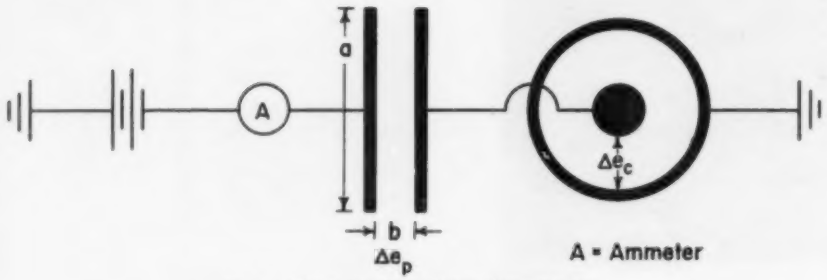


Fig. 1. Circuit for shape factor determination.

Δt = temperature difference, °F.
R = resistance to heat flow, °F. (hr.)/(B.t.u.)
A = area, sq.ft.
b = length of path traveled, ft.

These two equations bear a direct relationship to each other (*3, 4, 5*). However, in many cases of practical importance the heat flow problem is more complicated than is indicated by Equation (*2*), which applies only to heat transfer between parallel surfaces through a body of uniform cross section. Many times the surfaces are not parallel, nor is the cross-sectional area uniform. For such cases the cross-sectional area of the heat flow path becomes a function of the length of the path for heat transfer, and this length in turn may also vary from one part of the surface to another. An average area of the two surfaces of a body through which heat is being conducted sometimes has been used, but in many cases such a value of area, if used in Fourier's equation, will lead to erroneous results (*6*). Other methods have been used which give upper and lower limits between which the correct value must lie (*1*). Although these equations are quite simple in their application, they still leave much to be desired in the determination of heat transfer values.

Instead of the use of an approximation, Fourier's basic equation should be applied to a differential element and integrated between limits:

$$q_x = -k \int (\partial t/\partial X)\, dA_x \qquad (3)$$

where X = a direction normal to the differential element of area, dA. This equation is applicable to heat transfer in one direction only (the X direction), but similar equations can be written for heat transfer by conduction in the directions y and z.

To solve Equation (3), the following assumptions are made:

1. Steady state conditions or equilibrium exits, and so temperature is independent of time.
2. Heat transfer occurs only in one or two dimensions (one plane only).
3. The shape of the solid conducting heat is known and so its geometric configuration is known.

If one lets $\theta = (t - t_2)/(t_1 - t_2)$

where

t_1 and t_2 = the two terminal temperatures and
t = temperature at any point between t_1 and t_2,

This relationship may be used to transform Equation (3) above.

When $t = t_1$, then $\theta = \dfrac{t_1 - t_2}{t_1 - t_2} = 1$;

when $t = t_2$, then $\theta = \dfrac{t_2 - t_2}{t_1 - t_2} = 0$

If these are used as boundary conditions, Equation (3) becomes

$$q = -k(t_1 - t_2) \int \frac{\partial \theta}{\partial X}\, dA \qquad (4)$$

and θ is independent of t_1 and t_2, depending only on the shape of the body through which heat is being conducted. The integral of Equation (4) has dimensions of length and is Langmuir's shape factor. It can be considered as the ratio of a mean effective area, A_m, to a mean effective length, L_m, of the body conducting heat; that is,

$$\text{shape factor} = S.F. = \int \frac{\partial \theta}{\partial X}\, dA$$

The shape factor, therefore, depends only on the geometric configuration of the body conducting heat and is independent of temperature, heat flow, or any thermal property. The equation for heat transfer (*2*) can then be written

$$q = -k(S.F.)\Delta t \qquad (5)$$

or

$$S.F. = \frac{-q}{k\Delta t} \qquad (5a)$$

By the same reasoning a shape factor based on electrical measurements can be obtained from Equation (1):

$$i = -k_e(S.F.)\Delta e \qquad (6)$$

or

$$S.F. = \frac{-i}{k_e \Delta e} \qquad (6a)$$

In cases where an analytical solution is possible, such as heat flow by conduction between flat, parallel plates with insulated edges, Equation (3) can be solved to obtain

$$q = -k(A/b)(t_b - t_o) \qquad (7)$$

Comparing Equation (7) with Equation (5) makes it evident that the shape factor for this case is

$$S.F. = A/b \qquad (8)$$

where

A = area of one of the two exactly similar plates
t_o and t_b = temperatures of the two plates
b = distance between the two parallel plates.

For the case of concentric cylinders the analytical determination of the shape factor gives:

$$S.F. = \frac{2\pi L}{\ln(r_o/r_i)}$$

where

L = cylinder length (9)

This derivation is correct only for an infinitely long cylinder, but Equation (9) may be used for a finite cylinder if the ends are perfectly insulated or if their area is negligible compared with the whole area of the cylinder.

For the case of concentric spheres the analytical determination of the shape factor gives

$$S.F. = \frac{4\pi(r_i r_o)}{r_o - r_i} = \frac{2\pi(D_i D_o)}{D_o - D_i} \qquad (10)$$

where

r_i = radius of inner sphere
r_o = radius of outer sphere
D_i = diameter of inner sphere
D_o = diameter of outer sphere

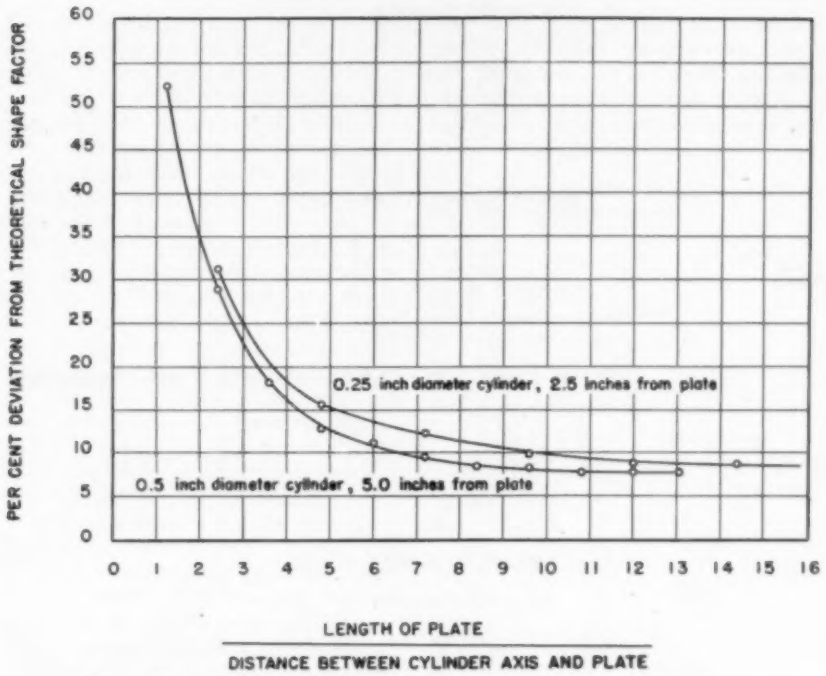


Fig. 2. Effect of plate length on heat transfer between a cylinder and a plate.

To determine the shape factor for conductive heat transfer from a cylinder to an infinite plate, special mathematical procedures usually are used. Conformal mapping (*7*) or numerical methods are general means of handling such geometrical configurations. By conformal mapping

$$(S.F.) = \frac{2\pi}{\ln\left[\frac{b}{r} + \sqrt{\left(\frac{b}{r}\right)^2 - 1}\right]} = \frac{2\pi}{\cosh^{-1}\left(\frac{b}{r}\right)} \qquad (11)$$

For application of Equation (11) the cylinder must have perfectly insulated ends, or it must be so long that the effects of heat conduction from the ends of the cylinder are insignificant, since the effect of the ends has not been considered in the derivation.

Experimental Apparatus and Materials

If two geometric configurations constructed of exactly the same materials, such as parallel plates and concentric cylinders, are connected in series according to Figure 1, then the shape factor of one can be experimentally determined if the shape factor of the other is known. This is illustrated as follows by assuming only two dimensional conduction and by assuming the depth of both the plates and concentric cylinders to be unity:

$$(S.F.)_p \text{ (for parallel plates)} = -\frac{i}{k_s \Delta e_p} = \frac{a}{b} \qquad (12)$$

$$(S.F.)_c \text{ (for concentric cylinders)} = \frac{-i}{k_s \Delta e_c} \qquad (13)$$

$$\frac{(S.F.)_p}{(S.F.)_c} = \frac{-i}{k_s \Delta e_p} \cdot \frac{k_s \Delta e_c}{-i} = \frac{\Delta e_c}{\Delta e_p} \qquad (14)$$

$$(S.F.)_c = \frac{(S.F.)_p \Delta e_p}{\Delta e_c} = \frac{a}{b}\frac{\Delta e_p}{\Delta e_c} \qquad (15)$$

This general method was used to determine the experimental value of the shape factor for various geometries. Previous investigators used three-dimensional models constructed of copper and glass sheets (*1, 8, 9*) or constructed complicated electrical networks (*10*). Since all the figures investigated in this work could have their third dimension expressed as unity, it was possible to carry out the experiments on a two-dimensional plane, greatly simplifying the experimental apparatus. The actual geometries to be investigated were drawn on conducting paper with silver paint, and a configuration of two concentric circles with a known shape factor was used to determine the shape factor of the desired figure. While either parallel plates or concentric circles would have served as a standard, the uninsulated ends of the plates could have affected experimental results, or transfer might have occurred from the desired figure to the side of the parallel plate configuration opposite the desired figure. Consequently, the closed figure of a circle was chosen as a primary standard, giving no possibility of end effects or transfer to the far side of the standard.

To prevent possible burning or electrolytic effects on the paper caused by any appreciable flow of current, it was decided to use resistance measurements instead of voltage measurements and to measure the resistances with a Wheatstone's bridge circuit. By Ohm's law,

$$i = \Delta e / R_e \qquad (1)$$

and so R_e could be substituted for Δe in Equation (15). Use of this type of measurement made it unnecessary to connect electrically the geometry being investigated with the concentric-circles standard (*11, 12, 13*). Instead, resistance was measured separately across the standard and across the shape being investigated, and the shape factor was then calculated by use of the equation

$$(S.F.)_x = \frac{(S.F.)_c (R_c)}{R_x}$$

where *x* refers to the shape being investigated, and *c* refers to the concentric-circles standard.

The conducting paper used was Teledeltos Paper, Type L, 31 in. wide. To give accurate results, the paper should have a uniform resistance in all directions. Actual experiments on the resistance of the paper indicate that while its resistance is essentially 2,500 ohms/sq.in., there is a variation from region to region as well as a variation in direction. The results of over forty measurements made on resistance in the direction of length of the paper gave extreme resistance variations in the range —7.0 to +4.5% from the mean with an average variation of +2.4%. The results of some twenty measurements made on resistance in the direction of width of the paper gave extreme resistance variations in the range —7.4 to +8.4% from the mean with an average variation of +2.8%. The results of over sixty measurements taken in both directions gave extreme resistance variations in the range —8.8 to +12.8% with an average variation of +3.3%. These variations in resistance are small enough to warrant the use of such paper for determining heat transfer shape factors. The silver conducting paint consisted of finely ground silver carried in a dispersing medium. The desired geometries were drawn on the paper with drafting instruments and then allowed to dry.

When the paint was thoroughly dry, the resistance of the concentric circles used as a standard and the resistance of the figures being investigated were measured by use of a Leeds & Northrup, Type S test set, No. 5300. A few readings were taken on a figure after it had dried and the readings repeated after the silver paint had been rubbed with a steel ball bearing. This was an attempt to gain a figure of uniform resistance, because it was thought that perfect contact might not have been made between the particles of silver after evaporation of the solvent. No appreciable change was

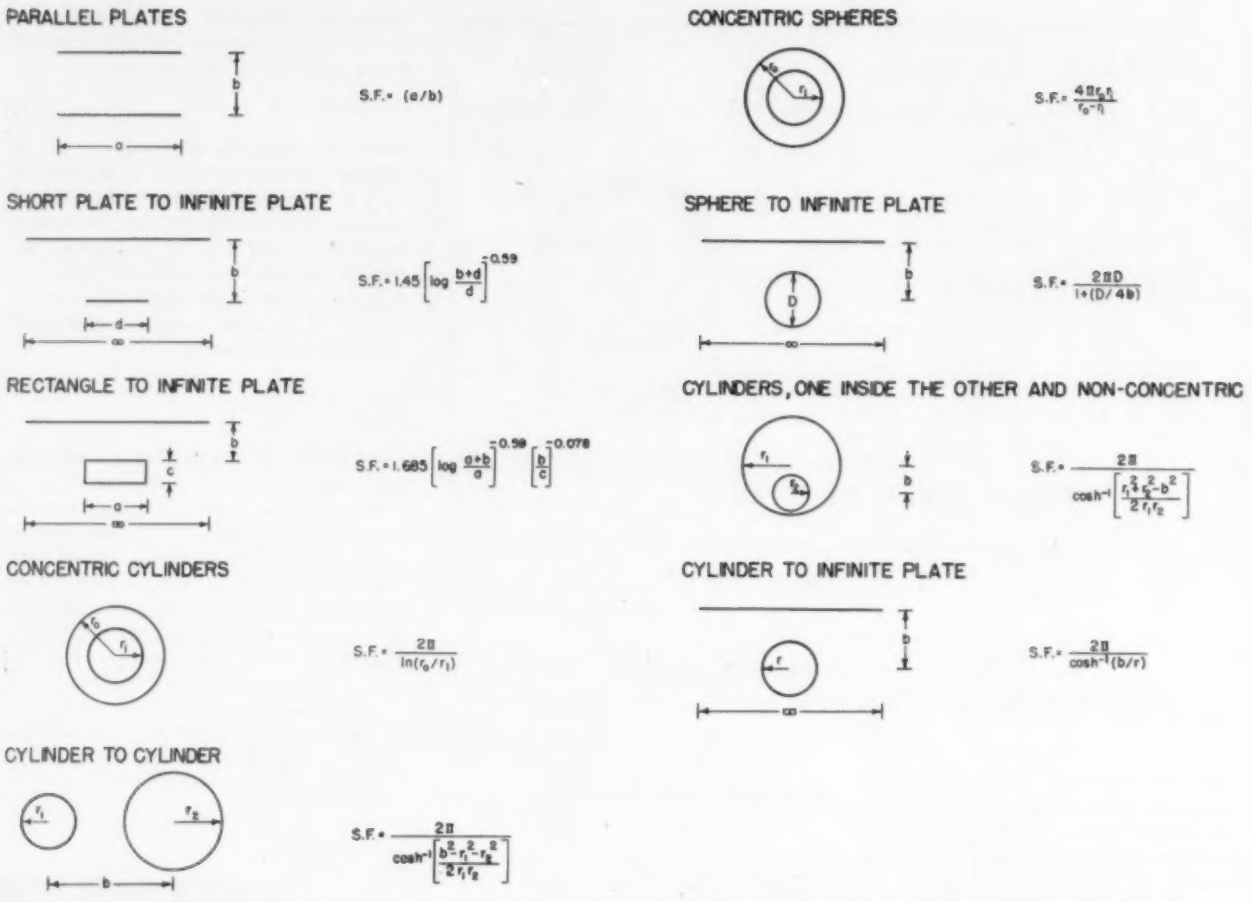


Fig. 3. Summary of shape factors for conductive heat transfer calculations.

found in the readings before and after rubbing, and so this process was discontinued for further readings.

In the determination of shape factors for heat transfer by conduction between a given figure and an infinite plate, it is obviously impossible to draw an infinite plate. Therefore, a plate as long as could be drawn conveniently was placed on a sheet of conducting paper; the desired figure, a circle in this case, was drawn at a point equidistant from the ends of the plate; and the shape factor for the system determined. Increments of plate length of 6 in. were then cut from each end of the plate and the shape factor was redetermined. Figure 2 shows the effect of the length of the so-called infinite plate on the shape factor. In all experimental determinations employing an infinite plate, care was taken to use a length sufficiently great to have no effect on the shape factor. Also, the plate in such cases was always extended completely to the edges of the paper so that no resistance effects could be obtained from the side of the infinite plate opposite to the geometry being investigated or from the ends of the plate. Extending the plate to the edge of the paper effectively insulates the ends of the plate.

In preliminary experiments to determine the shape factor for heat transfer by conduction from some given geometry to an infinite plate, attempts were made to utilize the same plate and different spacings from the plate by drawing the figure first at the greatest distance from the plate, taking resistance measurements, and then drawing the same figure at a closer distance to the plate and again taking resistance measurements. Such a practice was discontinued when it was found that erroneous results were obtained in the shape factor values even when the separation between the two geometries was several times the distance between the plate and the nearest geometry to the line.

Experiments and Results

Shape factors for conductive heat transfer between parallel plates, concentric cylinders, concentric spheres, and between a cylinder and an infinite plate were calculated from Equations (8), (9), (10), and (11) respectively and determined by the experimental method outlined above. Based on the calculated value as the correct value, the experimental results were consistently lower than the calculated results by approximately 6.5%, but the variation in percentage error itself was very small.

The shape factors for conductive heat transfer between parallel cylinders were determined experimentally and were calculated analytically by a method based on the work of Carslaw and Jaeger (*14*). Based on the calculated value as the correct value, the experimental results lie within the extreme range (+3.8%, −6.1%), whereas most of the experimental values have an error lying within a much smaller percentage range.

Errors of the size noted above give results well within practical usable limits since the accuracy of values of thermal conductivity, k, is considered to be approximately 10%.

The error is partially a result of variations in the resistance of the conducting paper; however, contact resistance between the paper and the silver paint figures or resistance between particles of the silver paint might account for some of the error. The use of two coats of paint, rubbing the painted surface as previously mentioned, or the use of larger contact area probes had no appreciable effect on this error. The test set used was accurately calibrated against a standard resistance both before

and during the period of measurements, and the error of the test set was not sufficient to account even for a small part of the error. While temperature changes affect the measured resistances, this effect can be neglected since readings of the standard and the figure being investigated were taken as nearly simultaneously as possible.

The most reasonable explanation for the consistently low values obtained in this case is concerned with the length of the infinite line and the width of the conducting paper. Since the limit of the paper width was 31 in., even though the line length was increased until no apparent effect was obtained on values of the shape factor, the bottom of the paper formed an obstruction to the attainment of an infinite field.

The shape factors for the other configurations reported were determined in an exactly similar manner, except those for conductive heat transfer from a sphere to an infinite plate. This shape factor was calculated from McAdams' equation (*15, 16*) and was not checked experimentally. In cases where it was possible to increase the size of a figure to obtain other desired readings, such a method was followed; for example, in the determination of the shape factor for conductive heat transfer between cylinders, the two small cylinders were drawn on a sheet of conducting paper at a determined distance between circle (cylinder with length of unity) centers. Readings of resistance were taken, and then a circle of larger diameter was drawn over one of the existing circles, and resistance measurements were again taken. In each case the entire circle was filled in with conducting silver paint to provide a greater surface of contact with the test-set probes.

It is believed that the work presented here materially reduces the assumptions which now must be made in calculating heat transfer problems involving geometric shapes not easily solved by pure mathematics, and the shape factors included will greatly reduce the time required to calculate results where an analytical solution is possible.

The results presented here are summarized in Figure 3. These results should be valuable particularly to industries using buried pipe lines or to those having pipe lines running side by side for appreciable distances and carrying materials of specific temperature.

Examples of Calculations

It is desired to calculate the exit-hot-fluid temperature and the heat transferred between a 6-in. O.D. pipe carrying water at a rate of 0.4879 ft./sec. and a 4-in. O.D. pipe carrying another colder fluid where each pipe is buried 4 ft. deep in a semiinfinite expanse of sand. The temperature at the entrance end of the 6-in. pipe is 250° F., and that of the 4-in. pipe is 100° F. The two pipes are parallel and separated by 9 in., center to center. What is the heat loss by the hot pipe and the temperature change in 1,000 ft. of pipe length?

k(sand) = 0.19 B.t.u./(hr.)(sq.ft.)(° F./ft.)
C_p(water) = 1.00 B.t.u./(lb.)(° F.)

Solution:

$$q = -k(S.F.)\Delta T$$
$$r_1^2 = (3/12)^2 = 0.0625$$
$$r_2^2 = (2/12)^2 = 0.0278$$
$$b^2 = (9/12)^2 = 0.5625$$
$$\pi r_1^2 = A_1 = 0.1963$$
$$\pi r_2^2 = A_2 = 0.0873$$
$$b^4 = 0.3164$$

(5)

$$2r_1r_2 = 0.0833$$

$$\frac{b^2 - r_1^2 - r_2^2}{2r_1r_2} = \frac{0.5625 - 0.0625 - 0.0278}{0.0833}$$

$$= \frac{0.4722}{0.0833} = 5.668$$

$$\cosh^{-1}\frac{b^2 - r_1^2 - r_2^2}{2r_1r_2} = 2.42$$

$$S.F. = 2\pi/2.42 = 2.596$$

$$q = -0.19(2.596)(1000)(250 - 100) = 74{,}670 \text{ B.t.u./hr.}$$

Flow of hot liquid = 0.4879 ft./sec.

$$Dup/\mu = \frac{0.5054(0.4879)(62.4)}{0.229(0.000672)} = 99{,}986$$

$$q = WC_p\Delta T = 74{,}670$$

$$0.4879\ \frac{\text{ft.}}{\text{sec.}} \times 0.2006 \text{ sq.ft.} \times \frac{62.4 \text{ lb.}}{\text{cu.ft.}}$$

$$\times \frac{3{,}600 \text{ sec.}}{\text{hr.}} = 21{,}990 \text{ lb./hr.}$$

$$74{,}670 = 21{,}990(1.00)(250 - T)$$

$$T = \frac{21{,}990(250) - 74{,}670}{21{,}990} = 246.6° \text{ F.}$$

250 — 246.6 = 3.4° F. temperature drop.

In addition, heat also will be lost by conduction from the hot pipe through the sand to the surface of the sand exposed to the air. This is calculated by Equation (5) through use of a shape factor for heat transfer from a cylinder to an infinite plate.

$$q = -k(S.F.)\Delta T$$
$$b = 4$$
$$r = (3/12) = 0.25$$
$$(b/r) = 4/0.25 = 16$$
$$(b/r)^2 = (16)^2 = 256$$

$$(b/r) + \sqrt{(b/r)^2 - 1} = 16 + \sqrt{256 - 1}$$

$$= 16 + \sqrt{255} = 16 + 15.9687 = 31.9687$$

Ln 31.9687 = 3.4648
1/3.4648 = 0.2886
$S.F. = 2\pi/3.4648 = 1.813$

If it is assumed that air temperature = 80° F.

$$q = -0.19(1{,}000)(1.813)(250 - 80) = 58{,}560 \text{ B.t.u./hr.}$$

$$58{,}560 = 21{,}990(1.00)(250 - T)$$

$$T = \frac{21{,}990(250) - 58{,}560}{21{,}990} = 247.3$$

250 — 247.3 = 2.7° F. temperature drop.

Total heat transferred:

74,670 + 58,560 = B.t.u./hr. = 133,230

Total temperature drop:

3.4 + 2.7 = 6.1° F.

Although this temperature drop, by lowering the effetive ΔT, would decrease the amount of heat transferred, it is too small to warrant a recalculation.

Literature Cited

1. Jakob, Max, "Heat Transfer," p. 399, John Wiley & Sons, Inc., New York (1950).
2. Langmuir, I., E. Q. Adams, and G. S. Meikle, *Trans. Am. Electrochem. Soc.*, **24**, 53 (1913).
3. Northrup, E. F., *Trans. Am. Electrochem. Soc.*, **24**, 85 (1913).
4. Nusselt, W., *Z. ges. Kälte-Ind.*, No. 1 and 2 (1915).

heat transfer

5. Jakob, M., *Z. ges. Kälte-Ind.*, **29**, 83 (1922).
6. Hering, C., *Trans. Am. Electrochem. Soc.*, **14**, 215 (1908).
7. Sokolnikoff, I. S., and E. S., "Higher Mathematics for Engineers and Physicists," McGraw-Hill Book Co., Inc., New York, 2 ed., p. 465 (1941).
8. Nukiyama, S., and H. J. Yosikata, *J. Soc. Mech. Engrs. (Japan)*, **33**, No. 1 (March, 1930).
9. Boelter, L. M. K., V. H. Cherry, and R. A. Johnson, "Heat Transfer," p. IV-34, University of California Press (1942).
10. Wilhelm, R. H., W. C. Johnson, R. Wynkoop, and D. W. Collier, *Chem. Eng. Progr.*, **44**, 105 (1948).
11. Awberry, J. H., and F. H. Schofield, *Proc. Fifth Internat. Congr. Refrigeration*, **3**, 591 (1929).
12. Schofield, F. H., *Phil. Mag.*, **10**, 480 (1930).
13. *Ibid.*, **12**, 329 (1931).
14. Carslaw, H. S., and J. C. Jaeger, "Conduction of Heat in Solids," p. 363-5, Clarendon Press, Oxford, England (1947).
15. McAdams, W. H., "Heat Transmission," p. 15, McGraw-Hill Book Company, Inc., New York (1942).
16. Rudenberg, R., *Elektrotech. Z.*, **46**, 1342-1346 (1925).

Illustration on page one of this article shows heat exchangers at the Esso Bayway Refinery (Linden, N. J.). *Courtesy Esso Standard Oil Co.*

promoted through the meetings and

ABSTRACTS

growing into management through professional maturity

R. P. Dinsmore | Goodyear Tire & Rubber Company, Akron, Ohio

Chemical engineers are skilled in the application of science to useful ends, either directly by the application of factory processes or indirectly by the analysis of business problems affecting manufacture and marketing in which a chemical engineering background is needed to map out future progress. By reason of their training chemical engineers fully appreciate the advantages of specialized equipment in facilitating their work, whether it be in the stages of manufacturing, or by control instruments which reduce the uncertainties of human operation, or by special testing equipment which allows the accumulation of more precise knowledge.

It is possible that this reliance upon science, physics, and mechanical engineering to produce results superior to those which can be obtained by the unaided human being has a tendency to develop in the chemical engineer a low evaluation of the importance of the human element. It is certainly true that the chemical engineer is inclined to place a high reliance upon the technical language of his profession, and to rate rather low the means of communication which deals with the nontechnical language; thus he is often misunderstood even by his fellow engineers.

The transition to the industrial atmosphere from the classroom, the laboratory, and the university pilot plant—even though training has been supplemented by some industrial practice school experience—is rather a mental shock to the average engineer. He ceases to be dealing with people whose primary objective is to impart information to him, and instead he is in contact with people whose chief preoccupation is to do a job or a whole series of interconnected jobs. He learns to his dismay that there are numerous people who do not think that chemical engineering is the ultimate of industrial or business activity, and, in fact, he finds out that there are many highly placed people in industry who do not even consider the profession of chemical engineering to be an important means of achieving their business objectives. He learns that even among the practicing chemical engineers the highest type of classical chemical engineering practice is not always employed, and that on many occasions speed is given a far higher rating than precision.

To the young engineer there appears to be an atmosphere of turbulence and confusion, obscure objectives, and lack of appreciation of him as an individual and of his profession as an instrument of accomplishment. Nevertheless, he is expected to find his way through with a minimum amount of help and to arrive at an orderly conception of the business organization he has joined and of his job in relation to it.

If he has been fortunate enough to become associated with a company or a department where his immediate superiors appreciate the importance of the human element and the necessity for adequate communication, he will, unless he is an extreme introvert, pass through the first few years of readjustment with a minimum amount of pain and stress. He will acquire his practical experience with his employer's problems without loss either of his pride in his profession or of the belief in the opportunity it offers him as an individual member of it. He will learn that adjustment of methods to the problem at hand is as vital a requisite in the accomplishment of his company's objectives as the proper selection of equipment for the watch-maker compared to the boiler-maker. Again, if a young engineer has more than the average gift of perceiving the advantages of utilizing coordinated group skills compared to isolated individual effort, he will be impressed with the necessity for communicating his ideas to others who do not have his depth of perception and understanding. In other words, he will begin to demonstrate talents as a leader, an administrator, and an executive.

Through these early stages of transition from chemical engineering in theory to chemical engineering in practice, older leaders in the profession can do much to direct the thinking and point the activity of the novice. The local sections of the A.I.Ch.E., offering personal contact with local leaders in the profession as well as in business and community activities, can help the adjustment of the young engineer to a great extent if an intelligent approach is used.

It is certainly one of the primary interests of the Institute to raise the level of training in the technical schools and universities so that the future engineer may enter his life work with an adequate technical background. This work is well in hand through the Accreditation Committee, and is further

promoted through the meetings and publications of the Institute.

However, the adjustment of the new engineer to his work and to the community in which he lives is of the utmost importance if his efforts are to be of maximum value to himself and to society. Therefore, the Institute has the threefold opportunity of helping to impress the teachers of chemical engineering with the necessity of preparing their students in some degree for the conditions they will later meet; in helping to educate the older engineers with regard to the importance of communication and the methods by which it can be improved; and by bringing the younger engineers directly into contact with the leaders in other types of community activities. The sooner the young engineer finds his place as a recognized and active member of his community, the more quickly will he fit himself into whatever branch of professional activity he may have selected for his career.

The young engineer must realize early that he has acquired unique responsibilities with, and because of, his professional training. If he does not gain this understanding, he will never make a professional man of the type which the Institute seeks to have as its members, and which reflects credit upon the profession. Obviously, if the older engineers with whom he associates do not exhibit an awareness of this responsibility by their own actions, it will be difficult for the young man to grow and develop such a sense of responsibility when planted in a barren soil.

However, even to those who are fortunate enough to perceive the growing power of chemical engineering in the accomplishments of our modern civilization, and to recognize their own responsibilities in that connection, a long and difficult road to travel lies ahead which involves the study of many things besides chemical engineering. They will learn that the response of people to group leadership is emotional and not technical; that the coordination of the elements which combine to create an industrial result involves many factors to which individuals frequently are subordinate; and that mature leadership depends upon a knowledge of the broad elements involved, an appreciation of how they must be balanced, and of how people can be persuaded to cooperate with a high level of effectiveness. They will discover also that their most rapid progress is made when they learn to understand what others are trying to do; to make others understand what they are trying to do; to take help from others when it is offered; and to offer help to others when it is needed.

ABSTRACTS

Abstracts of papers published in "Ion Exchange," Chemical Engineering Progress Symposium Series No. 14, Vol. 50 (1954), which may be obtained from Chemical Engineering Progress, 25 West 45 Street, New York 36, New York, for $3.25 for members and $4.25 for nonmembers.

Mixed-Bed Deionization at High Flow Rates

J. R. Caddell and R. L. Moison
Du Pont Company

The design of equipment for deionization of water need not be limited to the low flow rates usually employed in water softening. With beds of mixed strong-acid and strong-base ion exchange resin, increasing the flow rate from 5 to 100 gal./(min.)(sq.ft.) at any fixed level of influent impurities did not affect the capacity for producing pure water with a specific resistance of 10^6 ohm-cm. or better from a feed containing aluminum nitrate as the principal impurity. Raising the influent concentration from 3 to 192 p.p.m., however, almost doubled ion exchange capacity.

Chemical Engineering Progress Symposium Series No. 14, Vol. 50, 1 (1954).

Separation of Yttrium-Group Rare Earths from Gadolinite by Ion Exchange

F. H. Spedding and J. E. Powell
Ames Laboratory, Atomic Energy Commission

From a crude rare-earth concentrate of the mineral gadolinite, 82% of the available erbium and 50% of the ytterbium were obtained greater than 99.9% pure. The method is actually a single continuous elution process by which first low concentrations of individual rare earths are rapidly enriched by a primary step, then like fractions from parallel series are combined by rerouting the flow of eluants, and finally the enriched combined fractions are resolved by further elution.

Chemical Engineering Progress Symposium Series No. 14, Vol. 50, 7 (1954).

Hydroxide-Cycle Operations with Strongly Basic Anion Exchange Resins

R. M. Wheaton
The Dow Chemical Company

The common strongly basic anion-exchange resins contain a quaternary ammonium ion affixed to an insoluble polymeric structure. The most strongly basic resins, those containing only aryl and/or alkyl substitution, are the most stable chemically; however regeneration of these resins to the hydroxide-ion form from a common monovalent form, e.g., chloride, is inefficient except at low degrees of regeneration. A two-step method described here makes possible higher regeneration levels at improved caustic regenerant efficiencies.

Chemical Engineering Progress Symposium Series No. 14, Vol. 50, 43 (1954).

Ion Exchange Rate Mechanism

Herman Bieber, F. E. Steidler, and W. A. Selke
Columbia University

Shallow-bed techniques were employed to study rate mechanisms for silver-hydrogen exchange with Amberlite IR-120 cation-exchange resins. Variables included flow rate, resin-particle size, feed concentration, and pH of the feed. In all runs it was found that the chemical exchange reaction offered negligible resistance to exchange.

Chemical Engineering Progress Symposium Series No. 14, Vol. 50, 17 (1954).

Engineering and Economic Evaluation of Moving- and Fixed-Bed Ion Exchange Processes

N. K. Hiester, R. K. Cohen, and R. C. Phillips
Stanford Research Institute

This study to determine the most economical ion exchange techniques for the separation or removal of ionic components considered three modes of contacting the resin and solution: in a fixed bed of resin; in an intermittent, mixer-settler-type device; and in a continuous, countercurrent column. The only simple, yet precise, methods presently available for the design of all three processes apply to the exchange of trace components. The relative costs of the processes are presented for trace-ion separation, trace-ion removal, and gross-ion removal.

Chemical Engineering Progress Symposium Series No. 14, Vol. 50, 23 (1954).

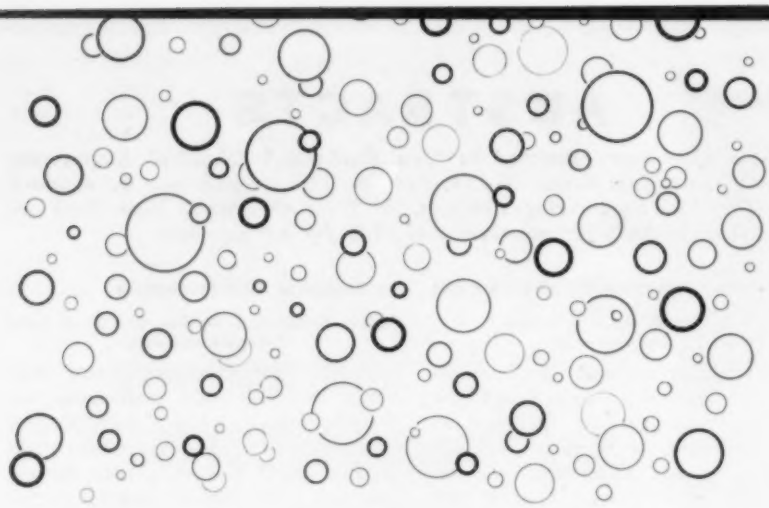
Countercurrent Ion Exchange with Gross Components: I. In an Equilibrium Stage Contactor; II. In a Continuous Countercurrent Column

N. K. Hiester, R. C. Phillips, and R. K. Cohen
Stanford Research Institute

For ion exchange separations under gross conditions, i.e., where nonlinear equilibrium isotherms govern, the variables affecting the separation of two or more ionic components in such a multicomponent system were considered in the development of a semigraphical design procedure, which enables the design of equilibrium stage units involving countercurrent contact between resin and solution. The method was extended to a continuous, countercurrent column.

Chemical Engineering Progress Symposium Series No. 14, Vol. 50, 51, 63 (1954).

The five remaining papers will be abstracted in a forthcoming issue.



particle-size distribution in some hygroscopic aerosols

G. R. Gillespie and H. F. Johnstone

University of Illinois, Urbana, Illinois

The selection and design of aerosol-removal equipment depend largely on knowledge of the size of the particle. In the present work the distribution of particle sizes of aerosols of sulfuric, phosphoric, hydrochloric, hydrobromic, and chlorosulfonic acids was measured by means of a four-stage high velocity jet impactor. The effect of the relative humidity of the air stream, the addition of foreign nuclei, the concentration of the aerosol particles and time on the size distribution was studied.

The aerosol was formed almost instantaneously by the rapid and continuous mixing of a hygroscopic vapor with a moist air stream. The particles attained equilibrium with their surroundings in a fraction of a second by taking up water vapor. If the number concentration was greater than 10^6 particles/cc., the particles continued to grow by coagulation. The particle size, which ranged between 0.1 and 6.0 μ diam., appeared to depend primarily on the method of formation of the nucleus. The size distributions followed the log-probability function from which the number of particles per unit volume of gas was obtained.

The jet impactor was shown to be readily adaptable to field work. Samples of sulfuric acid mist from the waste gases of a contact-acid plant showed the particle-size distribution to be nearly identical with distributions made from sulfur trioxide and water vapor under similar conditions in the laboratory.

The separation of dusts, fumes, and mists present in industrial aerosols is often necessary in order to prevent contamination of the atmosphere by obnoxious materials. This is particularly true in atomic energy installations, where the tolerance level is lower than in most industries and precautions must be taken against accidental releases of radioactive waste products. For high collection efficiencies the selection and design of removal equipment depend to a large extent on knowledge of the size of the particles. Unfortunately, few studies have been made on the size distribution in naturally formed aerosols. In the work reported here aerosols of sulfuric, phosphoric, hydrochloric, hydrobromic, and chlorosulfonic acids were formed in a continuous process by the rapid mixing of the hygroscopic vapors with moist air. The effect of the concentration of the particles, the relative humidity of the air stream, foreign nucleation, and aging on particle-size distribution was studied, and measurements were made on the size distribution of the acid mist in the stack of a commercial contact sulfuric acid plant. The results agreed closely with those found in the laboratory.

G. R. Gillespie is with E. I. du Pont de Nemours and Company, Eastern Laboratory, Gibbstown, New Jersey.

Formation of aerosols usually is due to the nucleation of a supersaturated mixture of a condensable vapor in air. The nuclei may be of foreign origin, such as minute crystals of sodium chloride, or they may be molecular clusters of the condensable vapor, which possess an excess of surface energy sufficient to produce the aggregate as a new phase. The clusters are formed by the stepwise addition of molecules which occurs continuously because of local fluctuations in the concentration of the vapor (*8*).

Experimental Equipment

The equipment consisted essentially of apparatus for generating or vaporizing hygroscopic materials, controlling the moisture content of the air stream, mixing the hygroscopic vapor and the air instantaneously, aging the aerosol, and separating the particles from the air according to their size (*7*).

HYGROSCOPIC VAPORS

Anhydrous hydrogen chloride and hydrogen bromide were obtained directly from commercial cylinders. The flow of the gases was controlled by means of a needle valve and glass capillary tubes, which served as critical orifices. Variation of the upstream pressure by means of a mercury cup gave flow rates between 50 and 1,500 cc./min.

Chlorosulfonic acid, phosphorus pentoxide, and concentrated sulfuric acid were vaporized in a dry nitrogen stream before being mixed with moist air. About 100 to 200 cc. of the material was placed in a 1,000-cc., three-necked flask, which was enclosed in a constant-temperature box. The temperature of the box was regulated according to the vapor pressure of the material being vaporized; for chlorosulfonic acid the temperature was maintained at 48° C., for phosphorus pentoxide, 205° C., and for concentrated sulfuric acid, 225° C. Preheated nitrogen was introduced into the flask at rates between 70 and 250 cc./min. through a 6-mm. glass tube which extended just above the surface of the material. The nitrogen and hygroscopic vapor left the flask through a chimney which was preheated several degrees in order to prevent condensation of the vapor before it entered the mixing chamber.

Sulfur trioxide was produced in a dry state by the oxidation of sulfur dioxide. Dry air containing 7% sulfur dioxide obtained from a commercial cylinder was passed into a converter at flow rates between 70 and 400 cc./min. The converter consisted of a 30-in. length of 1-in. stainless steel pipe mounted inside two Hoskins electric furnaces. The upper section contained a 12-in. bed of ¼-in. Berl saddles for preheating the gases to 480° C.; the lower section contained a 12-in. bed of vanadium pentoxide on zeolite pellets for catalyzing the oxidation at 400° C. The sulfur trioxide stream leaving the converter was filtered through a 3-in. bed of fine glass wool before entering the mixing chamber.

AIR STREAM

The relative humidity of the moist-air stream was controlled by the appropriate mixing of dry- and saturated-air streams.

One stream of compressed air was dried by passage through a 4-ft. bed of magnesium perchlorate. Steam was injected into a second stream, from which the entrained water was removed by passage through two 5-gal. traps in series. The streams were joined and filtered through a fine air filter and then passed into the mixing chamber at rates between 0.3 and 1.0 cu.ft./min. The average relative humidity was measured from a side stream which was fitted with a *U*-tube of magnesium perchlorate followed by a wet-test meter. Instantaneous humidity measurements were made by wet- and dry-bulb thermometry.

MIXING CHAMBER

The Lucite mixing chamber was 1¼ in. I.D. and ⅛ in. wide. The hygroscopic vapor entered one face of the chamber through a ½-mm. glass tube, around which eight ⅛-in. entry holes for the moist-air stream were spaced in a ¾-in. circle. The aerosol and excess air passed into the retention chamber through a similar arrangement of holes on the opposite face. The mixing time was about 10 msec.

RETENTION CHAMBER

The Lucite retention chamber was made in two sections, first 1¼-in. I.D. and 37 in. long and the second 5¼ in. I.D. and 152 in. long. The two sections were joined by a conical section with a 7° divergent angle. Eleven sampling ports were provided at various intervals along the tube, three in the first section and eight in the second. Static pressure in the tube was controlled by means of an exhaust fan and a 4-in. rubber valve.

SAMPLE TUBE

Samples of the aerosol were withdrawn through a ⅜-in. diam. brass tube which could be inserted into any of the eleven sampling ports. One end of the sampling tube was placed in the center axis of the retention chamber and faced upstream; the opposite end of the tube was connected to the jet impactor.

JET IMPACTOR

The distribution of particle sizes was determined by means of the high-velocity jet impactor described by Ranz and Wong (*12*). Jets with either rectangular or round opening were used, the parts being interchangeable so that several impactors might be used separately or in series. Usually a series of four impactors containing jets of decreasing openings was used. Table 1 shows the important dimensions of the jets and the approximate characteristic diameter of the particles impacted by each jet. An 18-mm.-diam. glass cup 5 mm. deep was used for collecting the particles. The aerosol particles which escaped impaction were drawn into a filter train of three filters, each containing about 1 in. of tightly packed fine glass wool. The filters and cups could be removed and weighed.

NUCLEI GENERATOR

The nuclei generator consisted of a helical element of nichrome wire supporting a core of glass wool created with either sodium chloride or ammonium chloride. The heating element was contained in an inverted 500-cc. round-bottom flask through which the air stream passed. When used, it was inserted between the air filter and the mixing chamber.

Table 1.—Dimensions of Jets Used in Cascade Impactor

A. Rectangular Jets

Jet	Jet width, cm.	Jet length, cm.	Gas velocity,* cm./sec.	D_{pc},† μ
G-1	0.1375	0.956	1400	2.69
G-2	0.0952	0.955	2020	1.86
G-3	0.0716	0.958	2680	1.40
G-4	0.0472	0.954	4090	0.85
G-5	0.0285	0.979	6600	0.50
G-6	0.0263	0.900	7490	0.44
G-8	0.0161	0.967	11800	0.25

* Flow rate 0.39 cu.ft./min.
† $\rho_p = 1.44$ g./cc.; $\mu_{air} = 1.8 \times 10^{-4}$ g./(cm.)(sec.).

B. Round Jets

Jet	Jet diameter cm.	Gas velocity,* cm./sec.	D_{pc},† μ
R-2	0.251	935	2.95
R-3	0.181	1850	1.72
R-4	0.138	3320	1.09
R-5	0.095	7040	0.60
R-6	0.077	11920	0.38

* Flow rate 0.1 cu.ft./min.
† $\rho_p = 1.48$ g./cc.; $\mu_{air} = 1.8 \times 10^{-4}$ g./(cm.)(sec.).

Procedure

The mixing of moist air and hygroscopic vapor resulted in instantaneous formation of an aerosol. At steady state conditions the aerosol at any particular point in the retention tube was assumed to have aged a definite time after its formation in the mixing chamber; therefore a continuous sample of the aerosol of known age, or retention time, was available. In a series of runs these samples were drawn through the jet impactors at various points along the tube to determine particle-size distributions of an aerosol at increasing retention times.

Air and the particular hygroscopic vapor under study were brought together in the mixing chamber at the desired conditions of relative humidity and mist loading. Steady state conditions were reached within 1 hr. The combination of jets which would best divide the aerosol into equal parts was selected and assembled with weighed cups and filters in series. Sampling was continued until several milligrams of particles was collected on each of the cups. The time of sampling varied from 2 to 60 min. After the sampling operation the cups and filters were immediately returned to weighing bottles to prevent change in weight from evaporation or condensation of moisture. The mass of particles in each size fraction was found from the increase in weight of the cups and filters. The cups were washed with water and the concentration of acid in the aerosol was determined by direct titration against standard 0.01 N sodium hydroxide solution. The sampling process was then repeated at another location in the retention tube.

Particle-Size Distribution

The diameters of the particles collected in each impactor stage were determined from the generalized calibration curve obtained by Ranz and Wong (*13*). They have assumed that all particles whose diameters are greater than the characteristic diameter of the stage will be impacted on the collecting cup and that all particles with smaller diameters will pass through the stage without impaction. The characteristic diameter, D_{pc}, may be calculated from

$$D_{pc} = \left(\frac{18\,\mu_{air} D_c}{C \rho_p v_2} \right)^{1/2} (\psi_{50})^{1/2} \qquad (1)$$

where $(\psi_{50})^{1/2} = 0.57$ for rectangular jets and 0.37 for round jets. The ratio of the mass of particles passing through the stage without impaction to the total mass of particles entering the stage represents the cumulative mass fraction of particles less than the characteristic diameter of the stage. By varying the diameter of the jet opening or the gas velocity through the jet or by using several stages of decreasing jet openings in series, the cumulative mass fraction can be determined at several diameters.

In this work the particle-size distributions in all the aerosols were straight lines on log-probability paper (*5*). Thus the size distribution of the aerosols is conveniently expressed in terms of two arbitrary constants: the mass median diameter, D_{mmd}, and the geometric standard deviation, σ_g. The value of σ_g is found from the ratio of the diameter of the 84.13% size to that of the 50.00% size. Other statistical diameters of the particles can be computed from the two constants by simple analytical expressions. Thus the number median diameter, D_{nmd}, may be calculated by

$$\ln D_{nmd} = \ln D_{mmd} - 3 \ln^2 \sigma_g \qquad (2)$$

and the mean volume diameter, D_v, which is the diameter of a particle whose corresponding volume divided into the total volume gives the total number of particles, may be calculated by

$$\ln D_v = \ln D_{mmd} - 3/2 \ln^2 \sigma_g \qquad (3)$$

From the mean volume diameter and the mist loading, ML, the number of particles per unit volume of aerosol can be found.

$$n = \frac{6ML \times 10^6}{\pi D_v^3 \rho_p} \qquad (4)$$

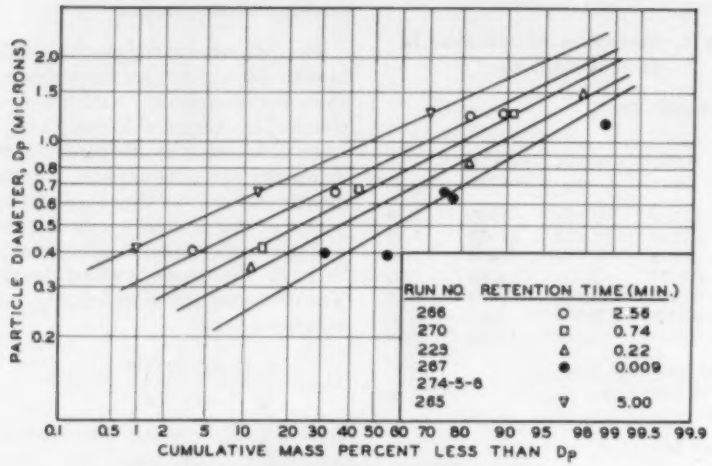


Fig. 1. Particle-size distribution of sulfuric acid mist. Mist loading, 0.56 mg./liter.

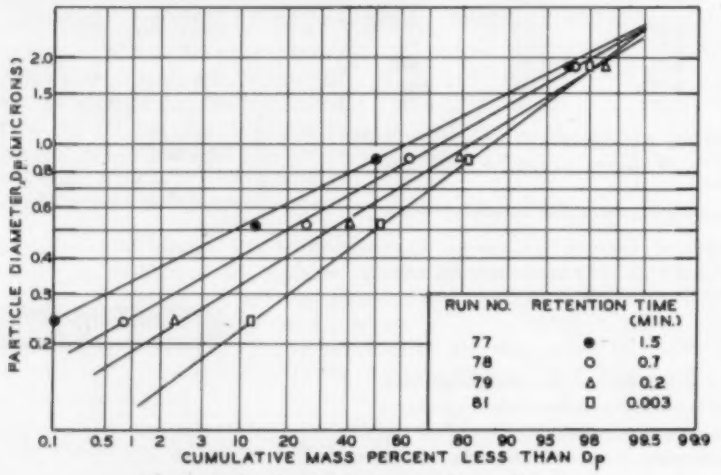


Fig. 2. Particle-size distribution of sulfuric acid mist. Mist loading, 2.8 mg./liter.

Sulfuric Acid Aerosols

Particle-size distributions of sulfuric acid aerosols made by mixing sulfur trioxide with humid air were measured for mist loadings of 0.11 to 2.8 mg./liter over a range of retention times from 0.003 to 5.00 min. The relative humidity of the air stream was varied from 10 to 90%. Typical curves of the size distribution are shown in Figures 1 and 2. The increase in size of the particles with time is apparent. In Figure 1, 50% of the mass of the aerosol is contained in particles smaller than 0.45μ diam. after a retention time of 0.009 min. Five minutes later only 2% of the mass is present in particles smaller than this size. In Figure 2 the mass-median diameter increases from 0.50 to 0.88μ during a retention time of 1.5 min. This growth of the particles conceivably might occur in two ways: by condensation of water vapor on the particle until partial-pressure equilibrium exists with the surrounding air or by coagulation of the particles. The experimental data show conclusively that growth by condensation must take place within the first 0.003 min. of the life of the aerosol, that is, before the first sample of the aerosol was drawn. If the volume of particles increases through condensation and therefore the number concentration of particles remains constant, then the mist loading should increase and the acid content of the particles should decrease with increasing retention time. In the aerosol represented in Figure 1, for example, the mean volume diameter increases from 0.31 to 0.81μ in 5 min. This volume change under the conditions of constant-number concentration would require a twenty-fold increase in the mist loading. Similarly, with a twenty-fold increase in mist loading, the acid content of the particles present originally as 25.5% sulfuric acid would be diluted to less than 1%. There was however no significant change in mist loading or in the acid content of the particles with time, and thus the particles came into equilibrium with the moist air almost instantaneously and the growth detected by the impactor measurements must have taken place by coagulation of the particles.

According to Whytlaw-Gray (*15*) the coagulation of aerosols follows a second-order process. Thus for uniform particles,

$$\frac{1}{n_2} - \frac{1}{n_1} = K(t_2 - t_1) \qquad (5)$$

where the coagulation constant K is a function of the particle size and the temperature. For the coagulation of heterogeneous aerosols consisting of particles having a wide range of sizes, the rate equation is complicated and a general solution cannot be attained. Cawood has shown, however, that the coagulation constant for heterogeneous aerosols is about 25% higher than that of a homogeneous aerosol (*3*).

Positive support for the coagulation theory is found in the general agreement of experimental and theoretical values for the coagulation constant. For homogeneous aerosols at 25° C., LaMer gives the value of K as 3.3×10^{-10} cc./sec. for 2μ particles and 9.9×10^{-10} cc./sec. for 0.1μ particles (*10*). Fuchs and Oschmann had previously calculated and confirmed experimentally the value of 12×10^{-10} cc./sec. for a homogeneous aerosol containing 1.5μ diam. particles (*6*). If these values are multiplied by the heterogeneity factor, 1.25, as suggested by Cawood, values of K for heterogeneous aerosols would range from 5×10^{-10} to 15×10^{-10} cc./sec. The values obtained from the slopes of the curves, such as shown in Figure 3, vary from 8.0×10^{-10} to 20.0×10^{-10} cc./sec.

The effect of the relative humidity of the air was most apparent in the acid concentration of the particles. In Table 2 a comparison is made of the acid concentration of particles in different size ranges and after different retention times for several humidities. The right-hand column shows the acid concentration in equilibrium with the temperature and relative humidity recorded for each run. The average weight per cent, as shown in the table, depends on the weight of particles in each size range. The particles collected in the filter were assumed to have the same acid concentration as those in the last stage. The differences between the average and equilibrium values are believed to be caused by experimental difficulties in controlling and measuring the relative humidity. Small fluctuations in room temperature could change the relative humidity as much as 10% during a series of runs. The Kelvin effect, which results in an increase of vapor pressure in very small droplets, is negligible for these sizes.

Table 2.—Concentration of Sulfuric Acid in Samples from Different Stages of the Impactor and after Different Times of Retention for Several Humidities

Run	Relative hum., %	Retention time, min.	Weight % sulfuric acid: Characteristic diam. 0.42μ	0.66μ	1.24μ	avg.	Theoretical
356	10	0.009	58.9	56.7	....	58.6	64.5
355	10	0.74	57.4	54.6	....	56.3	64.5
354	10	5.00	56.0	55.0	....	56.2	64.5
311	25	0.009	47.0	....	....	47	55.0
312	25	0.74	51.3	47.4	....	48.0	55.0
314	25	3.17	49.8	46.2	46.5	47.8	55.0
309	25	5.00	49.6	47.6	47.8	48.3	55.0
352	28	0.009	53.9	40.4	....	53.3	54.0
350	28	0.74	54.9	54.2	....	53.4	54.0
351	28	5.00	52.6	53.2	....	52.9	54.0
367	43	0.009	44.3	40.2	44.0	44.3	46.7
368	43	0.74	46.3	44.1	44.7	44.8	46.7
369	43	5.00	44.9	44.0	43.0	44.2	46.7
296	62	0.009	43.7	38.4	....	41.9	37.2
295	62	0.74	44.6	38.6	....	40.1	37.2
297	62	1.97	45.5	39.4	35.8	41.2	37.2
298	62	3.17	45.0	38.5	35.2	38.8	37.2
291	62	5.00	44.0	35.5	33.2	35.5	37.2

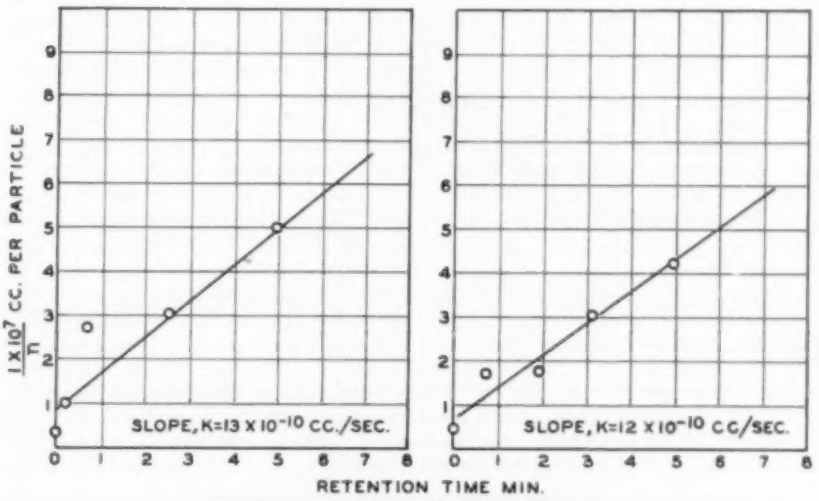


Fig. 3. Coagulation rate of sulfuric acid mists.

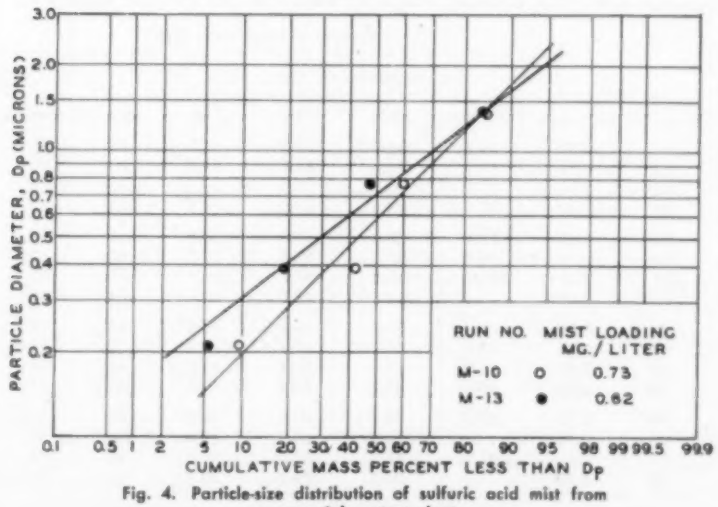


Fig. 4. Particle-size distribution of sulfuric acid mist from commercial contact plants.

The variation of mist loading affects the number concentration of the particles rather than their initial size. The ultimate effect of increasing the loading, however, is an increase in the particle size, because the rate of coagulation is proportional to the square of the number of particles present per unit volume; for example, aerosols having mist loadings of 0.43, 0.56, and 1.1 mg./liter were found initially to have the same mass-median diameter, 0.45μ, but after 5 min. retention time the mass-median diameters had increased to 0.84, 1.01, and 1.13μ, respectively.

The formation of the aerosol without the addition of foreign nuclei indicated that the critical limiting supersaturation of sulfur trioxide in moist air was greatly exceeded and that self-nucleation, which initiated spontaneous growth of the new phase, had taken place. The ease with which self-nucleation occurs in this system was emphasized by the fact that foreign nuclei failed to increase the number of particles found in the initial stages of formation. Only when the number of foreign nuclei introduced greatly exceeds the number which would form spontaneously can controlled nucleation be effected.

For comparison, sulfuric acid mists

aerosol collection

were prepared by the condensation of vapor from 98% sulfuric acid in a moist-air stream. Self-nucleation occurred in the absence of sulfur trioxide, but the number concentration in the initial aerosol was 1×10^3 particles/cc. compared with 2×10^7 in mists formed from sulfur trioxide under similar conditions. The mass-median diameter of the aerosol from sulfuric acid vapor was 4.6μ compared with 0.45μ of the aerosol from sulfur trioxide; the geometric standard deviation was 1.3 in both cases. The smaller number of nuclei which form spontaneously in sulfuric acid vapor permitted controlled nucleation of these mists. This fact has been the basis for the production of uniform mists of sulfuric acid by LaMer (*14*).

SIZE MEASUREMENT OF MISTS IN A CONTACT ACID PLANT

Measurements were made of the particle-size distribution of the sulfuric acid mists in the stack of gases of a commercial contact acid plant. The distribution of sizes, shown in Figure 4, followed the log-probability function and agreed remarkably well with the results obtained in laboratory experiments. In these tests the waste gases were sampled

from a point in the exit stack approximately 3 ft. above the absorption tower. The 15-mm. glass sampling tube projected 8 to 10 in. into the gas stream. A glass cyclone, designed to remove splash and spray droplets above the aerosol size range, as shown in Figure 5, preceded the four-stage jet impactor. Either a pump or an air aspirator was used to draw the sample from the stack.

Phosphoric Acid Aerosols

When phosphorus pentoxide vapor was mixed with moist air, a mist of liquid phosphoric acid droplets formed rapidly. Particle-size distributions were measured for mist loadings of 0.25 to 1.0 mg./liter at various retention times between 0.01 and 7.0 min. In general, the phosphoric acid aerosols behaved similarly to those of sulfuric acid from sulfur trioxide and water vapor, except that the mass median diameter was about twice that of sulfuric acid under the same conditions of mist loading and relative humidity. A comparison of Figure 6 with Figures 1 and 2 shows the similarity in the degree of heterogeneity and in the typical growth during retention. The coagulation constant of the mist shown in Figure 6 was 10×10^{-10} cc./sec. A comparison of the acid concentration of the particles is shown in Table 3. As in the case of sulfuric acid mists, there is general agreement between the observed and expected concentrations, and no significant change in the acid content of the particles with retention time was found.

Because of the larger size of the phosphoric acid particles, the number of particles per unit volume was much less than that in sulfuric acid aerosols of the same mist loading. At a loading of 0.5 mg./liter the number is less than 10^6 particles/cc., and the coagulation was too small to be detected. In the formation of such dilute aerosols the addition of foreign nuclei decreased the mass-median diameter from 1.6 to 1.3μ and produced a corresponding increase in the number concentration.

Hydrochloric Acid Aerosols

The role of hygroscopic nuclei in the formation of acid mists was studied by Philip and coworkers (*11*), who produced an aerosol by passing an air stream containing hydrogen chloride gas through a solution of sodium hydroxide containing a small amount of ammonia. The particles consisted of hydrochloric acid containing a trace of ammonium chloride. The mist loading varied significantly with the concentration of the alkali and with the amount of ammonia which it contained. Apparently, as the bubbles of the air containing hydrogen chloride formed at the end of the inlet tube in the alkali solution, ammonia diffused into the bubbles and combined with hydrogen chloride to produce nuclei of ammonium chloride on which water condensed as droplets, which then absorbed hydrogen chloride. In support of this mechanism, the authors found that as the equilibrium vapor pressure of water over the alkali solution was decreased, thus making it more difficult for the nuclei to acquire water, the amount of aerosol formed decreased. In fact, no aerosol was formed with a 50% solution of sodium hydroxide although nuclei of ammonium chloride were present.

In a later study of hygroscopic nuclei, Dessens (*4*) investigated the properties of particles of haze collected from the air. When placed in surroundings of

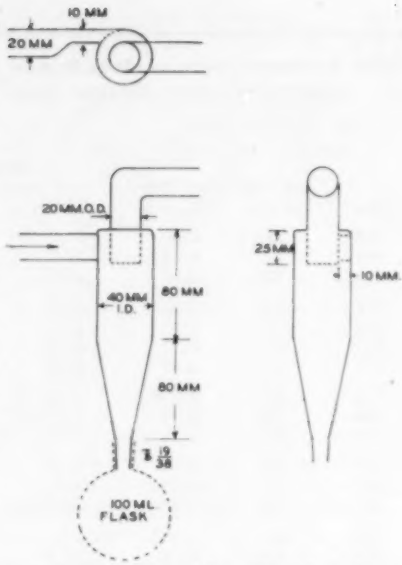


Fig. 5. Glass cyclone for separating aerosol particles. Dimensions shown are for 50% separation of 7μ particles with density 1.44 g./cc. for flow of 0.2 cu.ft./min.

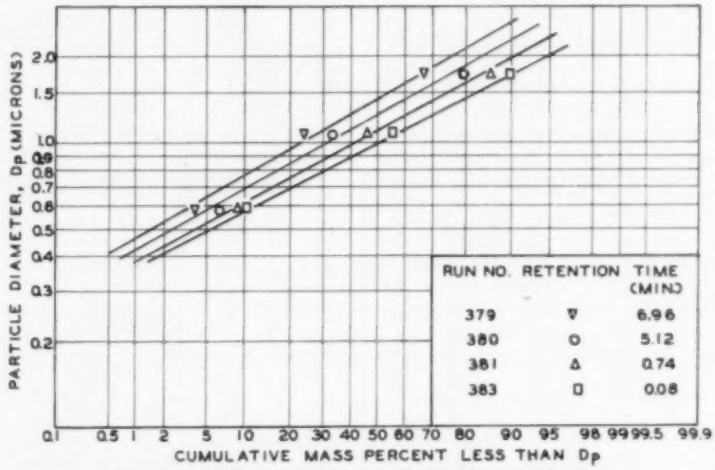


Fig. 6. Particle-size distribution of phosphoric acid mist. Mist loading, 1.0 mg./liter.

Table 3.—Concentration of Phosphoric Acid in Samples from Different Stages of the Impactor and after Different Times of Retention for Several Humidities

			Weight % Phosphoric Acid					
			Characteristic diam.					
Run	Relative hum., %	Retention time, min.	0.59μ	1.09μ	1.72μ	2.95μ	avg.	Theoretical
416	34	0.08	86.3	86.3	85.2	84.5	86	78
415	35	0.74	80.6	80.6	85.7	84.6	80	75
414	32	2.56	81.3	76.3	77.5	....	76	73
413	25	5.00	76.1	73.4	70.0	64.3	72	73
404	54	0.08	70.5	67.0	67.6	68.0	68	62
405	55	0.74	66.5	68.0	67.0	67.0	68	62
406	55	2.56	69.3	66.0	67.5	61.3	67	62
407	54	5.00	....	66.6	69.0	69.0	68	62
411	58	0.08	68.4	63.4	64.8	65.6	65	62
410	66	0.74	65.9	63.0	62.9	63.7	63	56
409	64	2.56	65.0	63.4	61.8	62.8	62	57
412	64	5.00	66.8	65.2	65.8	65.1	65	57
403	68	0.08	59.5	59.9	60.3	60.0	59	55
402	68	0.74	....	58.3	60.9	58.0	59	55
400	70	2.56	61.8	61.5	62.0	62.0	62	55
399	75	5.00	....	59.5	58.5	58.3	59	53

low humidity, each particle lost water by evaporation, leaving a crystal of salt which apparently was the original nucleus of the particle. When returned to air of high humidity, the particles absorbed moisture until equilibrium was reached with respect to the water vapor in the air. At 78% relative humidity the partial pressure of water vapor in the air is approximately equal to that of a saturated solution of sodium chloride or ammonium chloride. At higher relative humidities, Dessens found the particles to be liquid, and below 65% they were solid. Between these relative humidities both liquid and solid phases were present.

On the basis of these observations, experiments were arranged to study the formation of aerosols from anhydrous hydrogen chloride and moist air without bubbling the mixture through an alkali solution. If the air stream was free of nuclei and ammonia, the introduction of anhydrous hydrogen chloride gas to this stream did not produce an aerosol, regardless of the humidity of the air, in agreement with Philip's observation. The addition of sodium chloride or ammonium chloride nuclei to the air stream resulted immediately in aerosol formation when the relative humidity was above 78%.

Size-distribution measurements of hydrochloric acid aerosols were difficult to obtain because of the relatively high vapor pressure (about 3 mm. Hg) of hydrogen chloride over the acid droplets. Condensation of the vapors on the walls of the retention tube and the sampling equipment hampered continuous production of the aerosol and prevented sampling for more than 15 min. duration. At a mist loading of 1.0 mg./liter only 10% of the mass of the particles was less than 4.0μ in diam. The mass-median diameter was approximately 5.5μ and the geometric standard deviation was about 1.3. Because of the large particle size, most of the aerosol settled out in the retention chamber after 4 or 5 min.; this prevented any study of coagulation.

Hydrobromic Acid Aerosols

Anhydrous hydrogen bromide gas and moist air readily form an aerosol in the absence of foreign nuclei. Thus, contrary to the behavior of hydrochloric acid, hydrobromic acid is self-nucleating. Measurements of the particle-size distribution were made at loadings of 8 to 9 mg./liter and at relative humidities between 60 and 80%. The mass-median diameter was in a range of 4.0 to 4.5μ, and the geometric standard deviation was 1.15, which indicates a fairly homogeneous aerosol. Approximately 70% of the mass of the particles was between 3.5 and 4.5μ diam.

Aerosols from Chlorosulfonic Acid

The mixing of vapor from chlorosulfonic acid and moist air, free from foreign nuclei, resulted in the formation of droplets of sulfuric and hydrochloric acid because of the hydrolysis

$$ClSO_3H + H_2O \rightarrow H_2SO_4 + HCl$$

The particle-size distribution was measured at mist loadings between 0.2 and 1.0 mg./liter and at relative humidities from 10 to 90%. In size, the aerosol was similar to sulfuric acid mist from sulfur trioxide. In a typical series of measurements the mass median diameter of the newly formed aerosol was 0.6 to 0.7μ, and the geometric standard deviation was about 2.0. At loadings greater than 0.2 mg./liter, the number concentration was greater than 10^6 particles/cc., and coagulation occurred rapidly with an increase in the particle size, as shown in Figure 7.

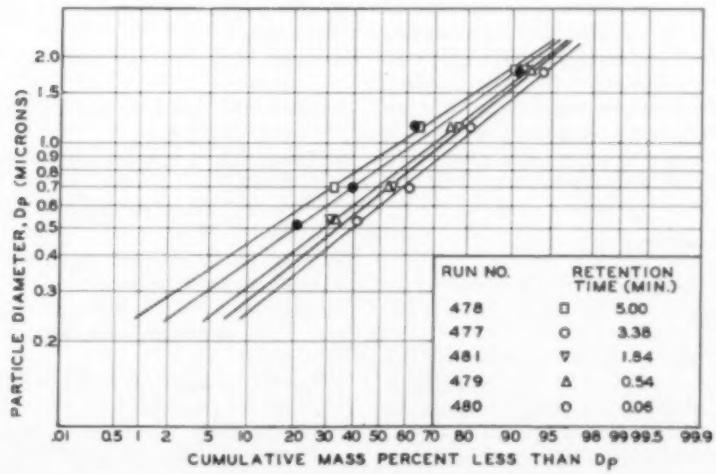


Fig. 7. Particle-size distribution of mist from chlorosulfonic acid. Mist loading, 0.2 mg./liter.

Analysis of the particles collected in the impactor showed that there was no chloride in the droplets smaller than 1μ in diam. Furthermore, the weight % of hydrogen chloride in the liquid was considerably less than predicted; for example, at a relative humidity of 65%, approximately 38% of the aerosol was sulfuric acid, less than 2% was hydrogen chloride, and the remainder was water. At the higher humidities, hydrochloric acid condensed on the walls of the retention chamber rather than in the aerosol phase, even though nuclei of sulfuric acid were readily available. At the lower humidities all the hydrogen chloride remained in the vapor state.

The introduction of foreign nuclei gave a clue to the mechanism of aerosol formation. At humidities below 78% nuclei of sodium chloride decreased the median-particle size slightly from 0.45 to 0.35μ, but the amount of hydrogen chloride in the droplets did not increase. At humidities above 78% nuclei of ammonium chloride increased the mass-median diameter to between 1 and 2μ (reproducibility of this value was difficult) and greatly increased the amount of hydrogen chloride in aerosol form. In view of the small size of the sulfuric acid particles, it appears that they are formed from sulfur trioxide vapor rather than from sulfuric acid vapor and, further, that liquid particles of sulfuric acid do not nucleate the hydrochloric acid aerosol as do the liquid particles of ammonium chloride solution. The latter fact is in agreement with the observation of LaMer and Gordieyeff (*9*), who report that the ability of sulfuric acid to nucleate condensable vapors vanishes below a vapor pressure of sulfuric acid of roughly 10^{-9} mm. Hg. Under the conditions of these experiments, the vapor pressure of sulfuric acid was 7.5×10^{-11} mm. Hg (*1, 2*).

aerosol collection

Conclusions

PARTICLE SIZE

It was expected that the size of particles of the various aerosols might be directly related to the equilibrium vapor pressure of the material used; that is, for a given concentration of the vapor, the substance with lowest equilibrium pressure would have its critical supersaturation exceeded most, and therefore a greater number of smaller particles should form. This idea was demonstrated by the relative sizes of sulfuric acid (from sulfur trioxide and water),

phosphoric acid, hydrobromic acid and hydrochloric acid mists. However, when sulfuric acid mist was formed from the vapors of a concentrated solution of the acid, the particle size was in the same range as that of hydrochloric acid mists. From these results it appears more probable that the particle size of hygroscopic aerosols depends primarily on the method of formation. If the hygroscopic vapor reacts with water vapor to form a new compound with release of considerable energy, the particle size of the aerosol is small, that is, below 2μ. If the hygroscopic vapor simply condenses and the liquid is diluted by absorption of water vapor without the release of a large energy of reaction, the particle size is relatively large, that is, from 2 to 6μ. Examples of the first class are sulfur trioxide and water to form sulfuric acid and phosphorus pentoxide and water to form phosphoric acid. Examples of the second class are the condensation of the vapors of sulfuric acid, hydrobromic acid, and hydrochloric acid with water to form aqueous solutions. In the reaction of chlorosulphonic acid vapor with moisture, both classes of aerosols are formed. The sulfuric acid appears in the smaller sizes and the hydrogen chloride remains in the vapor state unless the condensation is nucleated. If foreign nuclei are present, the hydrochloric acid mist exists only in the larger sizes. Within these two classifications the relation between particle size and vapor pressure previously discussed is satisfied. If measurements of the critical supersaturation limits of these materials were available, a more careful analysis of the dependence of size could be made.

NUCLEATION

The role of foreign nuclei in aerosol formation may be considered either to promote the formation of molecular clusters and thus decrease the critical supersaturation limit or to act as condensation nuclei *per se* and thus permit aerosol formation to take place at saturation. Supersaturation limits were not measured in this work, but the addition of foreign nuclei to the air stream generally resulted in decreasing the particle size and increasing the particle number. There were two exceptions to this behavior:

1. In the case of sulfuric acid mists formed from sulfur trioxide and water vapor, the introduction of additional nuclei did not affect the particle size of the aerosol. This agrees with LaMer's postulation (*10*) that self-nucleation of sulfuric acid condensation occurs and controlled nucleation can be obtained only by introduction of a large excess of foreign nuclei.

2. In the case of hydrochloric acid mists self-nucleation did not take place, nor did the introduction of foreign nuclei have any effect until sufficient water vapor was present to dissolve the salt used as a source of nuclei. This indicates that, at least in this case, solid foreign particles do not act as nuclei, but, when dissolved in water, the droplets absorb hydrogen chloride to form an aerosol.

JET IMPACTOR

The jet impactor, used singly or as a cascade, is a convenient device for the determination of particle-size distribution of liquid aerosols of uniform density. The range in the size of particles of unit density which are collected on the impactor cups varies from 0.2 to 5.0μ for sampling rates of 0.4 cu.ft./min. or less. The time required for sampling varies from 30 sec. for mist loadings of 10 mg./liter to 1 hr. for loadings of 0.1 mg./liter.

If the size distribution follows the logarithmic probability law, the number of particles per unit volume of aerosol can be determined from the actual density of the aerosol material and the mean volume diameter. The latter is calculated from data obtained by the impactor. In this way the impactor at once simplifies the tedious counting procedures that have been used in the past and extends the range for which number counts can be made to above 10^{10} particles/cc.

FIELD WORK

The combination of a suitably designed glass cyclone, a cascade impactor, and a glass-wool filter train can be used for a quick determination of the size distribution of mists and dusts for practical evaluation of the difficulty of a gas-cleaning job. The dimensions of the cyclone should be set so that the material collected in this instrument represents the fraction of the aerosol that can be removed easily in cyclonic devices. The percentage collection in the various stages of the cascade shows the increasing difficulty of attaining higher over-all collection efficiencies. The filter receives only the particles which are the most difficult to remove and require the most energy expenditure or the longest retention time in the collector.

Acknowledgment

This work is part of a cooperative investigation with the U. S. Atomic Energy Commission under Contract AT (30-3)-28 in the Engineering Experiment Station. Thanks are expressed to the Monsanto Chemical Company for permission to sample the gases from a commercial contact sulfuric acid plant to determine the distribution of particle sizes in the mist.

Notation

C = empirical correction factor for resistance of air to the movement of small particles. At room temperatures and atmospheric pressure, $C = 1 + 0.165/D_p$

D_o = width of rectangular jet, or diameter of round jet, cm.

D_p = diameter of aerosol particle, μ

k = C_p/C_v, for perfect gas = 1.40

K = coagulation constant, cc./sec.

ML = mist loading, mg. of particles/liter of gas

n = number of particles/cc. of gas

P_o = atmospheric pressure during calibration of jets, cm. H_2O

P_1 = pressure before jet, cm. H_2O

P_2 = pressure after jet, cm. H_2O

T_o = temperature during calibration of jets, ° K.

T_1 = temperature before jet, ° K.

T_2 = temperature at jet throat, $T^2 = T_1(P_2/P_1)^{(k-1)/k}$
(The temperature of the jet was taken to be that for frictionless adiabatic flow of a perfect gas.)

t = time, sec.

v_1 = velocity through jet, from calibration curve, cm./sec.

v_2 = average linear velocity at T_2 and P_2

$$v_2 = v^1 \sqrt{\frac{P_o P_1}{P_2^2} \times \frac{T_2^2}{T_o T_1}}$$

$(\psi)^{1/2}$ = dimensionless group, $\frac{(C\rho_p v_2/18\mu D_o)^{1/2}}{D_p}$

ρ_p = density of particle, g./cc.

μ = viscosity of air at T_2, P_2, g./(cm.)(sec.)

Literature Cited

1. Abel, E., *J. Phys. Chem.*, **50**, 260 (1946).
2. Abel, E., *Proc. Intern. Congr. Appl. Chem. (London)*, **11**, 309 (1947).
3. Cawood, W., and R. Whytlaw-Gray, *Trans. Faraday Soc.*, **32**, 1055 (1936).
4. Dessens, H., *Compt. rend.*, **227**, 630 (1948).
5. Drinker, P., and T. Hatch, "Industrial Dust," McGraw-Hill Book Co., Inc., New York (1936).
6. Fuchs, N., and N. Oschmann, *Acta Physicochim., U.S.S.R.*, **3**, 61 (1935).
7. Gillespie, G. R., Ph.D. Thesis Univ. Illinois (1953).
8. LaMer, V. K., *Ind. Eng. Chem.*, **44**, 1270 (1952).
9. LaMer, V. K., and V. A. Gordieyeff, *Science*, **112**, 454 (1950).
10. LaMer, V. K., E. C. Y. Inn, and J. B. Wilson, *J. Colloid Sci.*, **5**, 471 (1950).
11. Philip, J. C., *Trans. Faraday Soc.*, **32**, 1182 (1936).
12. Ranz, W. E., and J. B. Wong, *Ind. Eng. Chem.*, **44**, 1371 (1952).
13. Ranz, W. E., and J. B. Wong, *Arch. Ind. Hyg. and Occupational Med.*, **5**, 464 (1952).
14. Sinclair, D., and V. K. LaMer, *Chem. Revs.*, **44**, 245 (1947).
15. Whytlaw-Gray, R., and H. S. Patterson, "Smoke: A Study of Aerial Disperse Systems," E. Arnold and Co., London (1932).

Presented at A.I.Ch.E. Forty-sixth Annual Meeting, St. Louis, Mo.

Fig. 3. Petrochemical industry, 1954. Each dot represents one petrochemical plant.

trends in the expansion of the chemical industry

Henry Groppe | Monsanto Chemical Company, Texas City, Texas

The demand for a new chemical or group of chemicals is often accompanied by the growth of process plants in several locations to meet adequately the increasing need. Frequently economic considerations are such that a particular geographic location becomes the most favored for the expansion of production facilities. These economic advantages show themselves as proximity of raw materials and competitively favorable climatic conditions. Eventually, however, the advantages stimulating the original investment and the results of area expansion need to be reevaluated to ascertain whether or not the law of diminishing returns has begun to creep into the picture. The factor of raw-material proximity has to be weighed against transportation costs of finished products. The purpose of locating in any particular area for its decentralized atmosphere must be considered when it eventually loses its rural identity caused by industrial expansion and the impetus of integrating with existing facilities.

Growth of Petrochemical Industry

An example of an industry which has shown rapid expansion in recent years is the petrochemical industry. No one word symbolizes this industry so effectively as growth.

This industry has mushroomed to such an extent that it has more than doubled in size every five years for the past 10 or 15 years. This expansion (see Figure 1) indicates an increase in total petrochemical production from slightly more than 2 billion pounds in 1940 to approximately 25 billion pounds in 1953, and the present rate is expected to continue for some time. Estimates for future petrochemical production by the President's Materials Policy Commission and by others are also shown in Figure 1. These estimates vary, but the trend is upward at a continued high rate.

However, with such expansion come problems, such as water supply, decentralization, etc., and these are now being placed on the agenda of board conferences of the chemical process industries. Such is the situation confronting the Gulf Coast area.

In this examination of the petrochemical industry—particularly its importance in the over-all chemical industry—the word petrochemical is used in its broad sense, that is, any chemical recovered or derived from petroleum or natural gas and intended for chemical markets.

In 1953 approximately 22% of all chemicals produced were derived from petroleum and natural gas. This production represented a value of $3 billion, or approximately 50% of the estimated $6.14 billion total chemical production in the United States. The statistics on chemicals refer to basic or intermediate chemicals before upgrading to finished products, such as synthetic fiber, plastics, and synthetic rubber. The investment in plants for the production of these petrochemicals is more than $3 billion or about 50% of the estimated total $6.15 billion chemical plant investment. These figures are summarized in Table 1 and presented graphically in Figure 2.

Table 1.—U. S. Chemical Production

	Production, billion lb.		Value, $ billion		Investment, $ billion	
1953	Petro.	All Chem.	Petro.	All Chem.	Petro.	All Chem.
Aliphatics	16.2	19.7	2.4	2.5		
Aromatics	2.2	4.7	0.4	1.2		
Inorganics	6.9	89.9	0.2	2.4		
Total	25.3	114.3	3.0	6.14	3.0	6.15

The data in Table 1 (*1*) also indicate the breakdown of chemical production by type. In terms of dollar value petrochemicals supplied more than 95% of all aliphatics produced, approximately one third of the aromatics, and somewhat less than 10% of all inorganics. Various authorities have estimated that by 1960 to 1965 petrochemicals will supply 50% of the total chemical needs of this country. (*1, 2*).

This discussion on petrochemicals up to this point has made no reference to geography. Petrochemicals and the Gulf Coast are practically synonymous. It is estimated that 75% of the petrochemical production is located at the Gulf Coast. This predominance of the Gulf Coast in the petrochemical industry is graphically shown in Figure 2. A further illustration of this fact can be found in the map in Figure 3, where each dot represents a petrochemical plant. The question of paramount importance to this group is the extent to which the Gulf Coast will participate in this future growth. It is difficult to make any specific prediction. However, a careful examination of factors important in the growth of the Gulf Coast petrochemical industry should give some indication of future trends. Some of these factors listed here stimulated past growth and will continue to do so; others were stimulants in the past but are now acting to retard growth; and some are just becoming important.

Factors considered noteworthy are:

(1) raw materials and fuel
(2) transportation
(3) water
(4) labor
(5) taxes
(6) decentralization policies
(7) self-generating characteristics of rapid growth
(8) economics of scale
(9) integration

Raw Materials and Fuel

The most important single factor in the rapid growth of the Gulf Coast petrochemical industry thus far has been the abundance of relatively cheap raw materials and fuel in the form of petroleum and natural gas hydrocarbons. The most significant recent trend in this field has been the rapid increase in the price of natural gas. This is shown in Figure 4, which indicates estimated average industrial gas prices on the Gulf Coast (*3*). These prices include gas well-head price plus cost of transportation. Figure 4 also shows that during this same period the price of coal actually declined slightly (*4*). A comparison of these curves shows the steadily decreasing advantage of the Gulf Coast as a plant site from a fuel-cost standpoint.

Natural gas, of course, has many advantages as fuel. This fact has led to the continuous high rate of expansion of long-distance pipe-line facilities from the natural gas fields of the Southwest to the large fuel markets of the North and East. As a result of this competition for gas supplies, new contracts provide for starting well-head prices as high as 20 cents/Mcu.ft. The impact of rising gas prices is graphically illustrated by the recent establishment of a large electrochemical operation in Central Texas based on power generation from lignite.

It is difficult to estimate the limit to the possible rise in the price of gas. Some authorities have estimated that approximately 20 cents/Mcu.ft. is the maximum price that can be paid for gas at the well-head for transmission to the northeastern markets in competition with competing fuels. One possible limiting factor is the cost of manufacturing high B.t.u. gas on a large scale from the large supplies of coal in the Northeast. This increase in the price of natural gas will also be reflected to some extent in the prices of ethane and other hydrocarbon raw materials recovered from this source.

One of the characteristics of the chemical industry is its high degree of flexibility, which implies continuing competition between raw materials, processes, and products. This is particularly true in the case of raw materials. There are few of the thousands

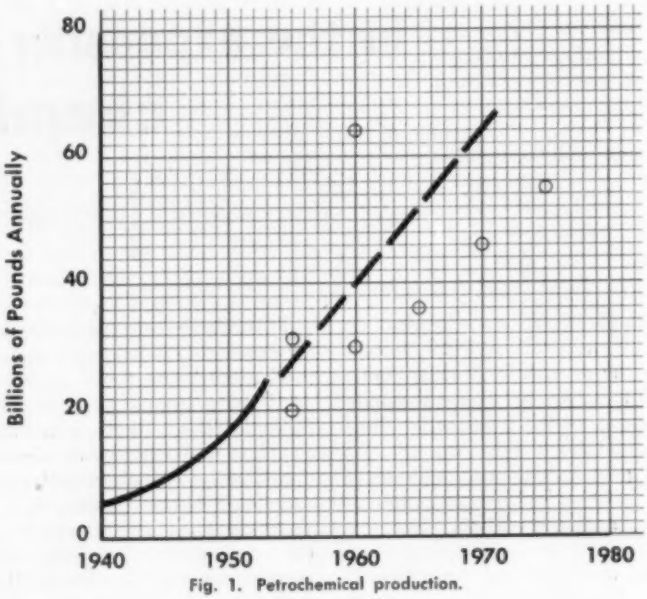


Fig. 1. Petrochemical production.

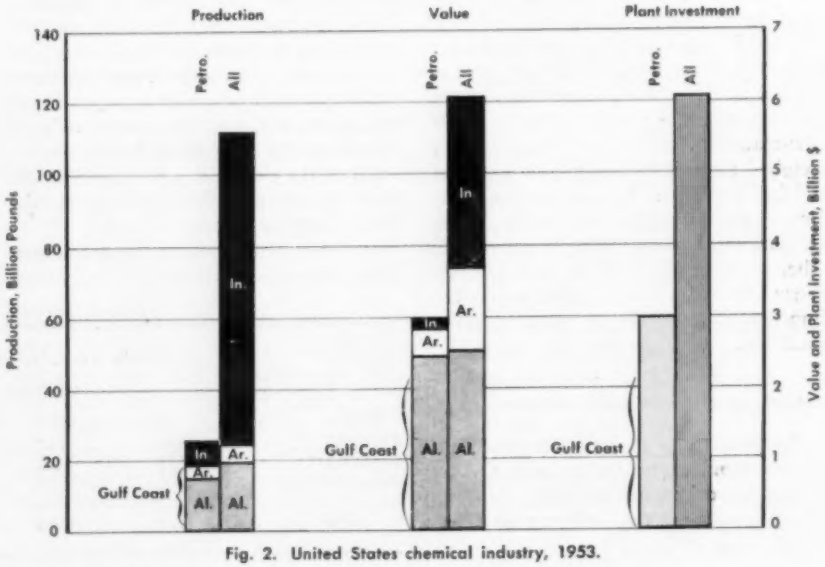


Fig. 2. United States chemical industry, 1953.

One of the most outstanding examples of

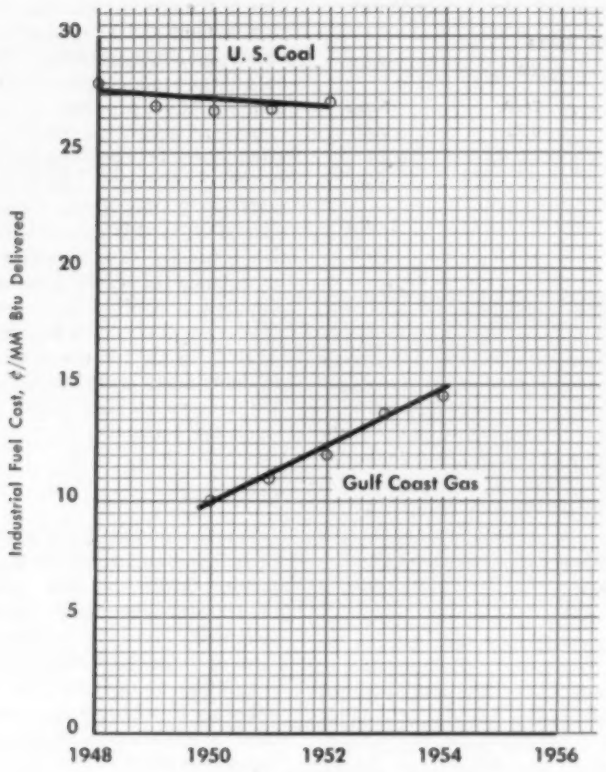


Fig. 4. Industrial fuel prices (3, 4).

of chemicals produced by the industry that cannot be made from alternate raw materials. In the case of the hydrocarbon chemicals there is constant competition between natural products, coal, and petroleum raw materials.

In the petrochemical field the raw-material flexibility and the resulting competition are reflected in several instances. The production of carbon black, where raw-materials cost is significant, is being rapidly converted from natural gas to petroleum fractions.

In the field of ammonia manufacture there are preliminary indications of a change in the trend from coal to natural gas. Two plants being built are to use residual fuel oil and, it is reported that other new plants are designed for later conversion from natural gas to oil. This trend has little direct effect on the Gulf Coast petrochemical industry, however, since ammonia plants are generally market oriented.

Another reflection of rising light hydrocarbon raw-material costs is the increasing interest in heavier hydrocarbon raw materials for ethylene production. Allied Chemical and Dye Corporation recently began production of ethylene from residual fuel oil at its Tonawanda (New York) plant. Another factor of definite long-range interest is the work being done in the field of coal hydrogenation.

Another important raw-material supply development is the rapid growth of the petroleum refining industry near ultimate consumer markets and the increasing importation of foreign crude oil. On the East Coast, for example, there was a 96% increase in refining runs in the 10-year period from 1943 to 1953. Since refinery gases constitute a prime petrochemical raw material, increased attention in the future will undoubtedly focus on growing refining centers such as this. With increasing importation of relatively cheap foreign crude oil this location provides a combination of cheap basic raw-material cost and proximity to ultimate consumer markets.

Transportation

Transportation costs have always been a major problem for Gulf Coast petrochemical producers since the major consumer product markets are in the Northeast. The cost of transporting raw materials must be continually compared with the cost of transporting finished products.

Two developments in the transportation of petrochemical raw materials will tend to retard growth in the Gulf Coast area since they provide lower cost raw materials nearer ultimate chemical markets. One of these is the long-distance gas-transmission industry which affords the opportunity for large-scale processing for recovery of ethane and heavier hydrocarbons remaining in the gas at or near the market-end of the pipe line. Because of the large scale of such operations, the contained ethane and heavier hydrocarbons are transported relatively cheaply. Operations of this type are being carried out at Tennessee Gas Transmission Company's pipe line in Kentucky and on the Panhandle Eastern Pipeline Company's system in Illinois.

The other development in this retardation process is the increasing transportation of propane and butane as L.P.G. in crude or products pipe-line systems which would also provide lower cost raw material for petrochemical manufacturing operations nearer consuming centers. In the past these materials were transported primarily by rail. However, Phillips is now transporting L.P.G. from producing areas to Chicago in its products pipe-line system. The proposed American Pipeline Company line for large-scale transportation of refined products from the Southwest to the East is reportedly designed for transportation of L.P.G. as well as other products.

plant location

A development to reckon with in the transportation of petrochemical products is the increasing movement of these materials to markets by barge and tanker. Transportation of chemicals by water from producing plants on the Gulf Coast to strategic points nearer market areas for storage, handling, and distribution has in many cases shown savings over direct transportation by rail or truck. The comparison of estimated transportation rates in Table 2 gives an indication of the advantage of water rates.

It should be pointed out that the water-transportation costs in Table 2 (5) do not include insurance, terminalling, or storage costs. Neither do they reflect increased working capital requirements because of the large quantities of material in storage and in transit required to accommodate large minimum load, slow moving water transportation.

Water

The problem of obtaining an adequate supply of good-quality water is becoming increasingly difficult, particularly in the lower Gulf area and more highly industrialized sections. This problem is

Table 2.—Estimated Transportation Rates

	$/100 lb.		
	Rail	Truck	Barge
Caustic, bulk .... Houston to St. Louis	0.76	0.76	0.47
Ethylene glycol .... Houston to Chicago	1.20	....	0.30
	Rail		Tanker
Ethylene glycol .... Houston to New York	1.27	....	0.35

of course common to many sections of the United States today. Rainfall in the Gulf Coast varies from about 50 in. in Louisiana to 15 in. in the Brownsville area. There are extensive underground water supplies in some sections but these are rapidly diminishing in many cases. However, irregular rainfall and steadily mounting water demands limit the supply available for further expansion. Competitive demands for water, particularly for use in irrigation, are steadily rising.

Surface storage is being expanded in some cases. A long-range program of integrated river storage and interlinking canals was recently proposed for the entire Texas Gulf Coast. Increasing attention must be given this problem to provide the water needed for a continued high rate of growth.

Labor

An adequate supply of skilled labor has grown up with the petrochemical industry and its expansion in the Gulf area. In time however the labor supply may fall short of the requirements of this territory since this industry is raw material oriented and supplies distant consumer markets, which of course represent the major sources of labor.

Taxes

Taxation is another consideration in expansion. As the various advantages the Gulf Coast enjoys over other areas decrease, tax structures and other political factors, such as zoning policies and regulatory actions, will become increasingly vital in determining the extent of further growth.

Decentralization Policies

In one sense the development of the Gulf Coast petrochemical industry was part of the trend on the part of many large corporations to decentralize their expanding operations. During World War II some companies were encouraged or required by the Government to decentralize for defense production security reasons and others followed a policy of decentralization for purely economic reasons. However, a point has now been reached of high regional concentration of the petrochemical industry on the Gulf Coast, and some decentralization from this area may be dictated from the standpoint of national defense.

Self-Generating Characteristics of Rapid Growth

One of the factors in the growth of an area is often described as the so-called self-generating characteristics of rapid growth. For example, the tremendous expansion in the Southwest has created favorable psychological conditions stimulating investment in that area. The success that some enterprises have had gives other enterprises confidence in risking capital. Service facilities such as machine shops and fabricators have been established to meet the needs of the particular location. Likewise, community and public facilities have been developed to meet the requirements of a rapidly growing population. The increase in population accompanying industry growth in turn stimulates further growth. These self-generating characteristics of growth will undoubtedly stimulate further growth of the area's petrochemical industry.

Economics of Scale

One of the characteristics of the petrochemical industry is the use of large-scale, highly automatic continuous processes. In processes of this nature unit production costs generally decrease significantly as plant capacity increases. This decreasing cost is effective usually throughout a fairly wide range of plant capacity. This factor has favored the installation of large-scale raw-material-oriented petrochemical plants in the Gulf Coast from which all markets are served. This operation also accommodates use of low-cost water and pipe-line transportation. These relatively low-cost petrochemical sources in turn attract chemical manufacturers interested in upgrading these materials. This economics of scale has been a real influence in the high growth rate of the industry. One of the most outstanding examples of this is Gulf Oil Corporation's ethylene manufacturing operation. Manufacture on a large scale combined with pipe-line transportation provides a relatively inexpensive source of ethylene that has attracted a number of chemical manufacturers interested in bringing such material to this area. Other probable operations of this nature will effect further growth. On the other hand, the importance of economics of scale in stimulating Gulf Coast petrochemical industry will diminish to some extent as areal demands for given petrochemical products reach sufficient volume to justify economic size plants located in given market areas.

Integration

Further integration of existing manufacturing operations is likely in the future. Most of the petrochemical growth has been in the area of basic chemicals. As the industry matures there will be increasing local vertical integration or upgrading of these basic materials to higher value products. The existing operations provide a broad, firm foundation for this growth.

Summarizing the data one can conclude that the petrochemical industry, 75% of which is located on the Gulf Coast, will continue its high rate of growth, increasing its share of total chemical production beyond the 50% it now represents.

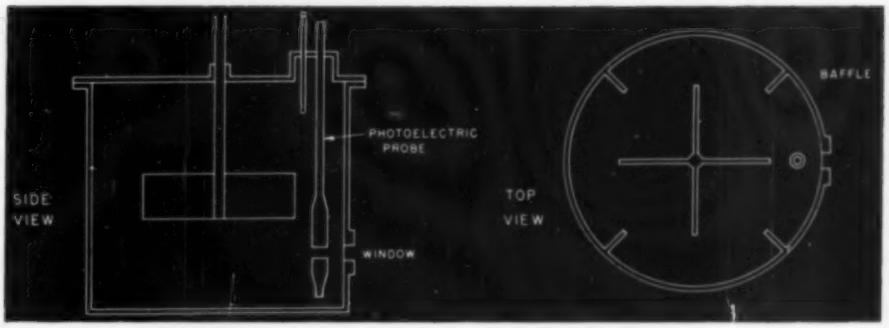
It is difficult to predict the extent to which the Gulf Coast will share in this growth, but opinions based on general trends can be offered. It appears that the Gulf Coast's dominance will be decreased somewhat, primarily because of increasing fuel and raw material costs and water shortages, but this decrease will be offset to some extent by increasing use of low-cost water transportation, further integration, and the self-generating aspects of rapid growth. As these trends tend to equalize the differences between the Gulf Coast and other areas, labor supply, taxation, and other political factors will become increasingly important.

Literature Cited

1. Bateman, R. L., *Petroleum Processing* (September, 1954).
2. Kuhn, W. E., and J. W. Hutcheson, *Petroleum Processing* (October, 1951).
3. *Petroleum Processing*, p. 1385, and private estimates (September, 1954).
4. *Electrical World*, p. 181 (Jan. 25, 1954).
5. Tighe, F. C., *Chem. Eng. News*, p. 4916 (Nov. 23, 1953).

Presented at Ninth Annual One-Day Meeting of South Texas Section October 22, 1954.

interfacial area in liquid-liquid and gas-liquid agitation



Theodore Vermeulen,
Gael M. Williams,
and Gordon E. Langlois

University of California, Berkeley, California

—Interfacial area and mean drop diameter, as determined from simple photoelectric cell measurements, offer a practical index to the effectiveness of mixing immiscible liquids, or gases with liquids.

Summary

1. Light transmission provides a simple means of measuring the degree of dispersion (expressed as specific interfacial area or as a mean drop diameter) of many immiscible mixtures.

2. The physical properties of the fluids which affect the degree of dispersion are interfacial tension, density, and (to a lesser extent) viscosity. The volume fraction of dispersed phase is also a factor.

3. The specific area can be estimated from known physical properties and mixing conditions by use of dimensionless correlations. However, the results of this paper apply only to a single mixing geometry.

4. The mass-transfer behavior of agitated heterogeneous systems can be predicted and analyzed by use of the results obtained.

The mixing of two mutually insoluble fluids, although a much-used operation, is understood only qualitatively at the present time. Power requirements for this type of mixing were studied by Miller and Mann (*15*) and by Olney and Carlson (*16*) on liquid-liquid systems and by Cooper, Fernstrom, and Miller (*4*) and Foust, Mack, and Rushton (*5*) on gas-liquid mixtures. Mixing of liquids and solids has been studied more thoroughly by Hixson and coworkers (*6, 7*) and by Mack and Marriner (*14*). Mixing of heterogeneous phases is dynamic and readily reversible by contrast to the blending of miscible fluids with which Rushton (*19*) and MacDonald and Piret (*12*), among others, have also been concerned.

For most mass-transfer operations the transfer rate is expressed as a product of total interfacial area of the net molecular transfer across each unit of area. It is desirable to adhere to this pattern in dealing with agitated systems. Theoretically, of course, the area and the unit-transfer rate both depend upon physical properties, and these properties can be used directly to correlate the observed rates. However the variables are so numerous that measurements of over-all mass-transfer rate have never been made in which all the physical variables were specified, and no serious attempts at correlation have been made. As a further complication the effects of the physical variables upon the over-all rate will change as one transfer step or another becomes the limiting factor.

It has appeared, therefore, that direct measurement of the interfacial area or of the effective average droplet size would contribute to an interpretation of mass transfer in stirred tanks. A similar investigation by Clay (*3*) dealt with drop sizes in closed-circulation flow of liquid-liquid mixtures through pipes, but did not lead to a conclusive correlation. The present study makes it possible to extrapolate certain rate-behavior data on liquid-solid systems, and to interpret previous observations on liquid-liquid and liquid-gas systems. Moreover there is now available for the first time a simple instrumental method of defining the interfacial area, which should be useful both in plant operation and in process development work.

Experimental Program

The following physical variables appear to influence the steady-state interfacial area, as produced during agitation:

1. physical properties of the two fluids
2. volume fraction of dispersed phase
3. stirring speed
4. factors characterizing the geometry of the agitator.

Messrs. Williams and Langlois are associated with the California Research Corp., Richmond, Calif.

For complete tabular data, including Tables 4 and 6, order document 4316 from A.D.I. Auxiliary Publications Photoduplication Service, Library of Congress, Washington 25, D. C., remitting $1.75 for microfilm or $2.50 for photoprints.

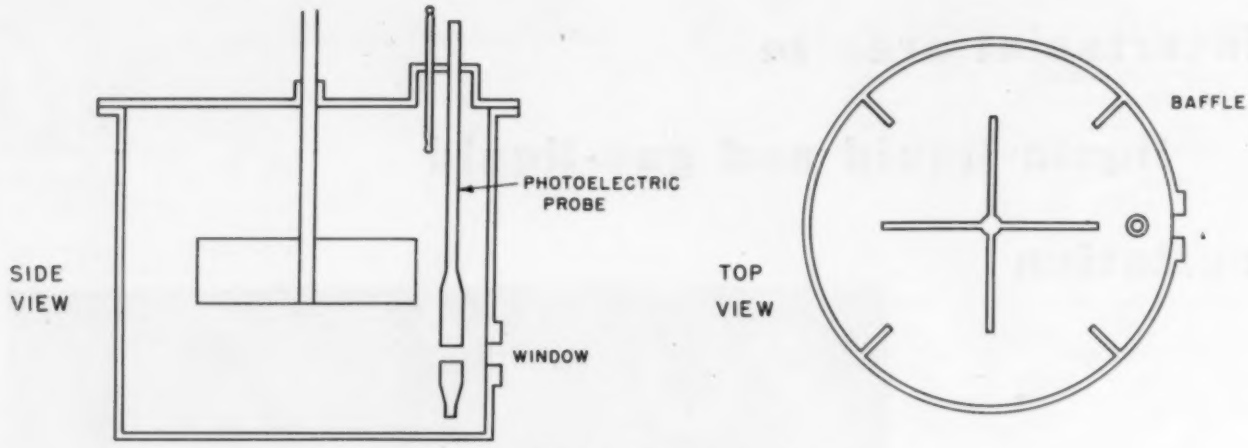


Fig. 1. Schematic diagram of mixing tanks.

The present study deals mainly with variables 1, 2, and 3.

MATERIALS

The properties of the fluids which were considered to be pertinent were viscosity, density, interfacial tension, and perhaps the density difference ($\Delta\rho$) between the two phases. Fluids were selected to cover a wide range of these variables. Liquid viscosities were varied from 0.38 to 184 centipoises, and liquid densities from 0.69 to 1.60 g./cc. Gas viscosities were corrected for the mole fraction of organic vapor by the use of the equations of Bromley and Wilke (*2*) but showed only a small variation. The interfacial tension varied from 3.6 to 55.1 dynes/cm., and surface tension from 18.9 to 72.8 dynes/cm. These were measured, after mixing, by use of the DuNuoy-type ring tensiometer, and were found to agree well with published values. A value of $\Delta\rho$ as low as 0.03 g./cc. was measured.

The effect of volume fraction of dispersed phase was investigated over the range from 10 to 40% in liquid dispersions, and from 2 to 30% in gas dispersions. Earlier studies of liquid-liquid mixtures by Long (*11*) had shown that, in the absence of surface-active agents, the transition from one phase continuous to the second phase continuous occurs in the vicinity of 50 vol. %. This criterion was found to be valid for most cases in the present investigation.

The fluids studied are listed in Table 1, together with the physical properties of interest. Technical-grade solvents were generally used and in addition to the pure materials, several blends were used to obtain desired physical properties.

AGITATION EQUIPMENT

Agitators used in this investigation consisted of two cylindrical stainless steel tanks essentially 10 and 20 in. in diam. (and in height) respectively. The impeller was a four-bladed flat paddle centered both horizontally and vertically in the tank. Four vertical baffles each one-tenth the diameter of the tank, mounted against the tank wall at right angles to it, were spaced at 90-degree intervals around the tank; this number of baffles has been shown by Mack and Kroll

Table 1.—Fluids Used in Agitation Studies (Properties measured at 68° F.)

Fluid	Refractive Index N_D^{20}	Density g./cu.cm.	Viscosity poises	Interfacial Tension vs. Water dynes/cm.	Surface Tension vs. Satd. Air dynes/cm.	Density of Satd. Air $\times 10^3$ g./cu.cm.	Viscosity of Satd. Air $\times 10^4$ poises
Water (distilled)	1.3330	0.998	.0100	....	72.8	1.194	1.79
Carbon tetrachloride	1.4601	1.595	.00980	39.9	26.8	1.819	1.59
						0.903*	1.58*
Carbon disulfide	1.6273	1.265	.00378	35.2			
Isooctane (2,2,4-trimethyl pentane)	1.3910	0.693	.00517	46.5	18.9	1.388	1.56
Methanol	1.3288	0.792	.00597	....	22.6	1.217	1.64
n-Butanol	1.3991	0.802	.0295	....	24.6	1.210	1.82
Ethylene glycol	1.4318	1.115	.199	....	44.7	1.205	1.82
Diethylene glycol	1.4475	1.117	.365	....	44.1	1.205	1.82
Kerosene	1.4445	0.821	.0181	39.7	24.8	1.205	1.82
White oil	1.4779	0.871	1.84	55.1	31.3	1.205	1.82
Blend A							
(White oil, Kerosene)	1.4734	0.861	.654	50.7	26.1	1.205	1.82
Blend B							
(White oil, Kerosene)	1.4652	0.845	.156	49.6	29.0	1.205	1.82
Blend C							
(CCl_4, Isooctane)	1.4162	1.033	.0065	43.0			
Blend D							
D_1: Glycerol, water	1.4383	1.200	.438	3.6**			
D_2: iso-Pentanol	1.4099	0.847	.0661	3.6**			
Blend E							
E_1: iso-Pentanol	1.4019	0.828	.0405	4.1**			
E_2: Water	1.3369	0.994	.0118	4.1**			

* Helium as the gas phase.
** Between two phases as indicated.

(13) to be sufficient for a condition of "standard baffling." A cooling coil was soldered to the outside of the tanks, through which cooling water could be circulated for temperature control. The impeller was driven by a 1-hp. repulsion-induction motor through a Speed-Ranger conical-gear reducer for adjusting the stirring speed. Complete dimensions of the agitation equipment are given in Figure 1.

All runs were made with completely filled tanks in order to eliminate the asymmetric geometrical effect of a free gas surface and to avoid complication of the interfacial and composition terms in the liquid-liquid runs which would result from a third (gas) phase.

A window was provided in the side of the small tank through which photographs of the emulsions were taken. The probe for measuring light transmission was inserted through a small chimney in the top of the tank, and the probe was located directly in front of the window.

In most runs the volume swept out by the impeller in each revolution was 8.0% of the total tank volume. This is a larger fraction than is encountered in industrial-scale mixing, but was utilized in order to insure as uniform a distribution of emulsion as possible. The 10-in. tank was used for most of the measurements, with the probe in a fixed central position, as shown. Exploratory runs with the probe inserted near the top of the tank showed the same drop diameters for some systems and larger values for others. Thus the values reported approach the *maximum* interfacial area per unit volume (specific area) and represent the average specific area in some of the cases.

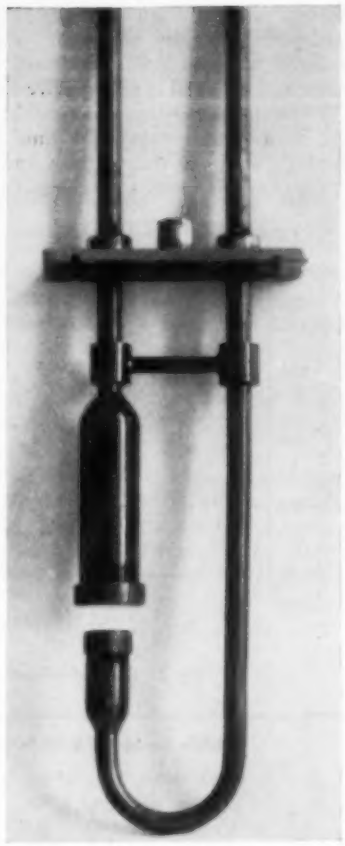


Fig. 2. Probe used in photoelectric measurements.

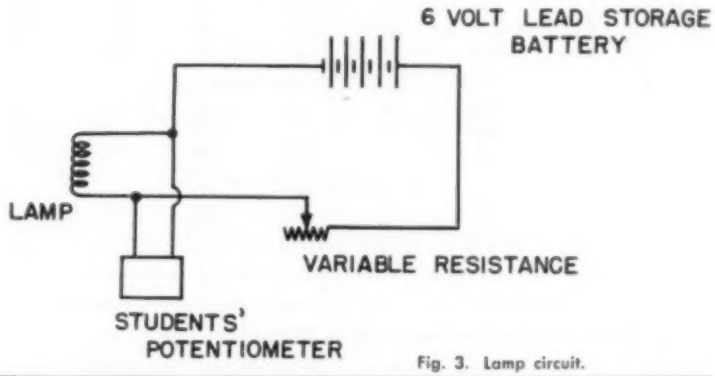


Fig. 3. Lamp circuit.

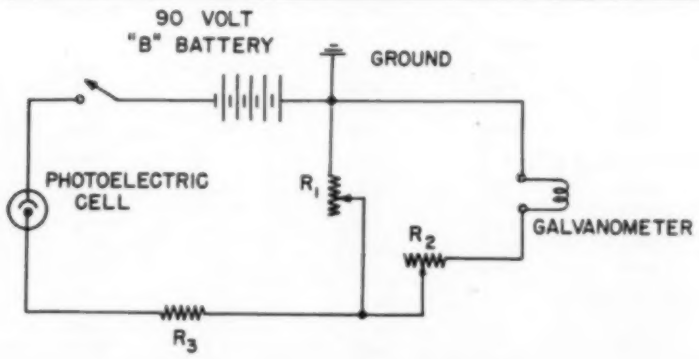


Fig. 4. Photocell circuit.

The investigation has been extended to cover the effects of impeller and baffle proportions (relative to tank dimensions) upon particle size, together with studies of power consumption; of rate of approach to the steady-state droplet diameter and its effect on uniformity of dispersion throughout the tank; and of the minimum agitation needed for uniform bulk mixing. These results will be reported in a separate paper.

PHOTOELECTRIC MEASUREMENTS

The light-transmission method of measurement is described elsewhere (10). The probe (see Figure 2) used was equipped with a penflash lamp bulb and an RCA phototube located behind sealed windows which were 1.00 cm. apart. Circuit diagrams used for the lamp and the phototube are shown in Figures 3 and 4. The light-transmission readings were calibrated by high-speed photographs of the emulsions on which droplet-size counts were made to evaluate the interfacial area per unit volume. Calibration in the dispersed-gas region was obtained by interpolation between a measurement of a stable glycerol-air emulsion and the values in the liquid-liquid region.

It was found that a plot of the extinction ratio (I_o/I, where I_o is initial intensity and I is transmitted intensity) against interfacial area per unit volume of mixture (specific area, A) gave a straight line with an intercept of unity, corresponding to the equation

$$\frac{I_o}{I} = \beta A + 1 \qquad (1)$$

Empirically, β was found to depend upon the ratio (m) of refractive index of the dispersed phase to that of the continuous phase. In theory β is independent of drop-size distribution, as long as all the particles are spherical or nearly so. Correction of refractive indices for the wavelength difference between the sodium D line (5721 Å and the maximum sensitivity of the photocell (7500 Å) did not appreciably alter m; hence the D-line values were used without correction. A plot of β against m is given in Figure 5, which applies for the specified probe geometry if the probe surfaces have low reflectance. The function is seen to consist of two smooth branches, each of which comes in (with a finite slope) to $\beta = 0$ at $m = 1$. Moreover, the two branches are not symmetrical.

Equation (1) evidently applies only to mixtures of completely transparent fluids, without residual cloudiness after settling, in which the reduction of light transmission is due entirely to scattering at the interfaces. The choice of liquid-liquid mixtures was limited because many liquids that were tried produced a residual cloudiness in one or both phases.

In order to determine the steady-state specific area at a given mixing condition, the light-transmission value was observed, β was read from Figure 5 with m from measured refractive indices, and A was calculated by use of Equation (1).

OPERATING PROCEDURE

All runs were made at atmospheric pressure; higher pressure runs on gas-liquid mixtures represent an interesting possible extension of the present study.

In making each experimental run the tank was cleaned and rinsed thoroughly with one of the liquids to be used. The appropriate volume of continuous phase was then charged. The light-transmission probe was placed in the tank and the initial light intensity I_o determined. This was done before adding the dispersed phase, in order to prevent droplets of the latter from adhering to the glass surface and causing an erroneous determination of I_o. The second phase was then measured in, cooling water was circulated to bring the temperature to 68° F. (20° C.), and agitation was started. The temperature was measured by a thermometer inserted into the tank. Temperature control was maintained by adding ice as necessary to the reservoir of the cooling-water circulating system. By this means it was possible to control the temperature easily to within ±1° F.

The stirring speed was measured and recorded. The light intensity was determined periodically and recorded. When the light transmission had ceased to change and had held constant more than 15 to 30 min., the system was considered to be in a steady state. The time required to attain a steady state varied from system to system, and ranged from less than one minute to more than two hours. Each mixture was run at from three to nine different speeds.

Results

From these specific area measurements a mean drop diameter was computed as the diameter of a drop that

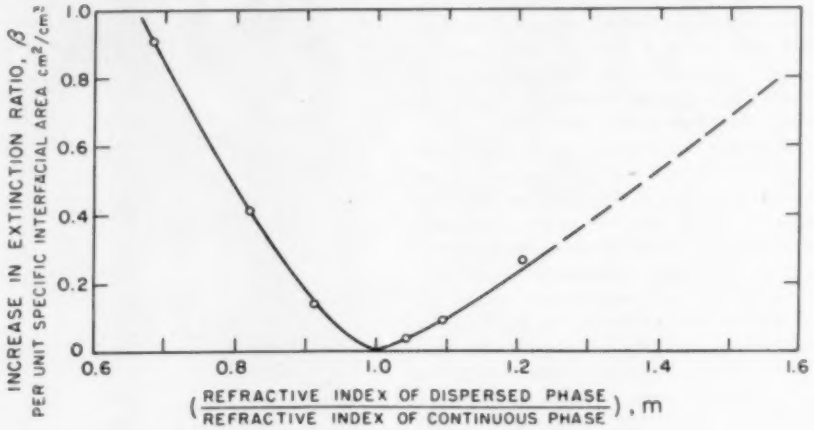


Fig. 5. Effect of refractive-index ratio on light transmission.

Table 3.—Mean Bubble Diameters for Gas-Liquid Mixtures

$X = N^3L^{5/3}\rho'\mu_D/\sigma^{4/3}\mu_C^{1/3}\rho_C^{1/3}$ $\quad Z = (d\sigma\rho_C\mu_C)^{1/3}/\mu_D(f_\phi)^{1/3}$

$Y = N^3d^{8/3}L^{4/3}\rho'/f_\phi^{5/3}\sigma$ $\quad (L = 17.2$ cm. throughout)

ϕ	N rev./sec.	I_o/I	d cm.	d/f_ϕ	X	Y	$Z \cdot 10^{-4}$	$\frac{Y}{Z} \cdot 10^4$
			Helium in CCl_4 ($W = 11.2$ cm.)					
.0844	4.25	3.86	.162	.168	.186	.982	.254	3.86
	5.00	4.78	.122	.127	.248	.847	.237	3.57
	5.83	5.60	.101	.105	.337	.838	.222	3.77
			Air in CCl4 ($W = 11.2$ Cu.)					
.0844	4.09	3.49	.186	.194	.169	1.16	.271	4.28
	5.01	4.32	.140	.146	.254	1.07	.246	4.36
	5.84	5.10	.113	.118	.346	1.03	.228	4.52
			Air in CCl_4 ($W = 4.18$ cm.)					
.0844	4.88	3.90	.160	.167	.238	1.27	.258	4.92
	5.29	4.28	.141	.147	.281	1.21	.247	4.91
	6.02	4.95	.117	.122	.364	1.15	.232	4.96

Table 2.—Mean Drop Diameters for Liquid-Liquid Mixtures

ϕ	N rev./sec.	I/I_o	d cm.	d/f_ϕ	$\frac{N^2L^3\rho'}{\sigma}$	$\frac{N^{1.2}dL^{.8}\rho'^{.6}}{\sigma^{.6}f_\phi}$	$\frac{(d\sigma\rho_C\mu_C)^{1/3}}{f_\phi^{1/3}\mu_D}$	$Re_C \cdot 10^{-4}$
				CCl_4 in Water ($L = 17.2$ cm.)				
.202	1.80	.250	.0363	.0288	563	.0745	22.5	5.0
	2.69	.160	.0207	.0164	1260	.0692	18.6	7.5
	4.00	.132	.0166	.0132	2770	.0890	17.3	11.2
	6.67	.105	.0127	.0101	7700	.126	15.8	18.6
				Water in Blend C				
.202	2.43	.312	.0446	.0354	710	.105	21.8	10.7
	2.72	.280	.0382	.0303	890	.103	20.6	12.0
	3.03	.231	.0295	.0234	1110	.0912	18.9	13.3
	3.76	.188	.0227	.0180	1710	.0910	17.3	16.5
	4.16	.147	.0169	.0134	2100	.0765	15.7	18.3
				Water in Isooctane				
.199	2.52	.598	.0747	.0593	611	.162	21.3	9.41
	3.15	.502	.0506	.0402	952	.143	18.8	12.2
	4.26	.408	.0345	.0274	1750	.140	16.5	16.0
	4.50	.385	.0315	.0250	1950	.136	16.1	16.7
	5.34	.331	.0248	.0197	2740	.132	14.8	20.0
	6.67	.267	.0182	.0144	4270	.126	13.3	25.3

has a surface-to-volume ratio equal to the quotient of observed specific area over volume fraction. It may be calculated from the relation

$$d = \frac{6\phi}{A} \qquad (2)$$

where

ϕ = volume fraction of dispersed phase
A = specific area (sq.cm./cc., if d is in centimeters).

This mean drop diameter was used in subsequent correlations of the effects of the physical variables.

Experimental measurements are summarized in Tables 2, 3, and 4.* The mean diameters ranged from about 0.003 to 0.1 cm. for the liquid-liquid mixtures, in 144 measurements, and usually from 0.1 to 0.5 cm. for the gas-liquid mixtures, in 146 additional measurements reported in Table 3.

* See footnote on page 85F.

REPRODUCIBILITY

Although the degree of dispersion is now known more closely than from any previous measurements, the reproducibility of the data was relatively poor. This can be seen in Figure 6, where the values of the light transmission are plotted against stirring speed for five duplicate runs with carbon tetrachloride in water. The maximum deviation from the mean was almost 20%, and the average deviation was about 5%. A similar, slightly smaller, deviation for gas-liquid mixtures is shown in Figure 7.

The light-transmission measurements could usually be made with an accuracy within one per cent; care was taken to check the I_0 value periodically, in order to test for possible drifts in photocell output and, if necessary, to correct for them. Thus the deviations appeared to be due largely to variations in the emulsions themselves.

In some runs the sequence of determinations was from low speeds to higher speeds and in others the reverse. No consistent differences were observed either in the final steady-state light transmission, or in the rate of approach to the steady state.

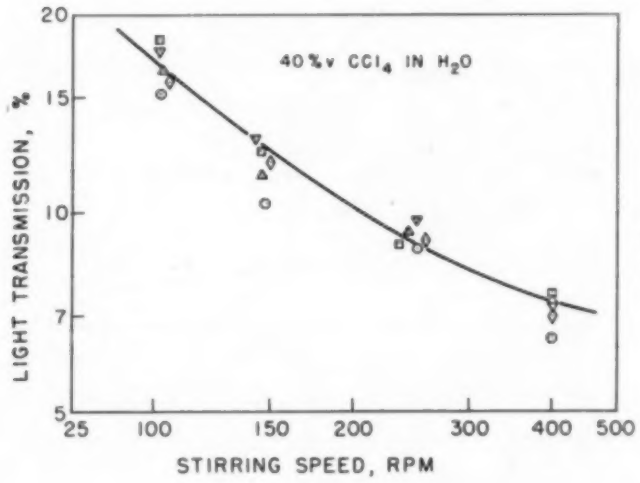


Fig. 6. Reproducibility of photoelectric data.

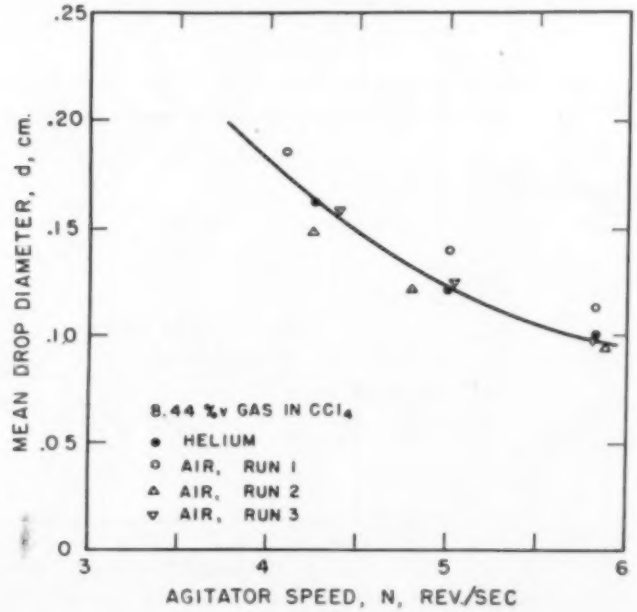


Fig. 7. Effect of gas density.

Effect of Surface-active Agents

Larger deviations were shown between different mixtures having the same nominal composition than between duplicate runs on the same mixture. Although these deviations were not accompanied by any appreciable change in interfacial (or surface) tension, they are still attributed to dynamic effects involving concentration of trace impurities at the interface.

In the air-kerosene mixtures (Table 4) drop diameters measured approximately one-tenth the diameters in other gas-liquid systems and were completely inconsistent with them in terms of the effects of measured physical variables. Bottle-shaking tests on multiple samples of a large number of organic liquids showed that the ability to produce fine dispersions of air was a random one and was associated with impurities. Comparison of the air-kerosene and air-isooctane results indicates that the kerosene used was not pure hydrocarbon, and the results on it have been discarded. Interestingly the kerosene-water results were not out of line with those of other liquid-liquid mixtures.

Effect of Coalescence

Some liquid-liquid and all the gas-liquid systems showed an increase in drop diameter at points away from the impeller. This behavior was found to be characteristic of systems in which the steady-state dispersion is approached too rapidly to measure the time of approach to steady state, including mixtures of water with carbon disulfide, butanol, and a few others.

Effect of Incomplete Mixing

Samples of the agitated mixture were withdrawn from a point near the probe in order to determine the local volume fraction. In a few runs at the lowest speed it was found that complete mixing had not been achieved; most of these runs were eliminated from subsequent calculation.

EFFECT OF PHYSICAL VARIABLES

Agitator Speed

As expected, the mean drop diameter decreased as the stirring speed was increased. For liquid-liquid systems Figures 8a and 8b show logarithmic-scale plots of d vs. N for some typical runs. The plots are often slightly concave upward, for the liquid-liquid mixtures, rather than exactly linear, but neither a theoretical explanation nor an empirical pattern has been found for the curvature. Within the probable accuracy of the data a straight-line plot is believed to apply, with an average slope of -1.2; i.e., for liquid-liquid mixtures

$$d = (\text{const.})\ N^{-1.2} \qquad (3)$$

A similar trend was observed for gas-liquid mixtures (see Figure 6). The average slope in these cases was somewhat steeper, with good linearity on logarithmic plots, giving

$$d = (\text{const.})\ N^{-1.5} \qquad (4)$$

Agitator Width, W

In the gas-liquid runs a wide impeller (with $W = 11.2$ cm., but the same diameter as before) was used in order to increase the amount of gas in suspension. The bubble diameters measured with this wide impeller were essentially the same as those with the standard impeller at the same volume fractions.

Interfacial (or Surface) Tension, σ

In both the gas and the liquid dispersions, it was observed that smaller drop diameters are generally obtained at lower σ. Variations in interfacial tension were obtained through an appropriate choice of organic liquids, although this did not give an independent variation. In order to minimize possible differences between the dynamic and static values of σ, the use of surface-active agents as third components was avoided. Thus the precise effect of σ could be evaluated only by dimensional analysis; this will be shown later.

Viscosity

Figure 8a shows a variation in continuous-phase viscosity of from 1.81 to 65.4 centipoises under conditions where the density of that phase varied from 0.821 to 0.861 g./cc., and the interfacial tension varied from 39.7 to 50.7 dynes/cm. Minor variations in drop diameter (10 to 20%) show little, if any, effect of the large change in viscosity. Figure 8b shows an even wider variation in dispersed-phase viscosity, accompanied by a density change from 0.693 to 0.871, and an interfacial tension change from 46.5 to 55.5. In this case the drop diam-

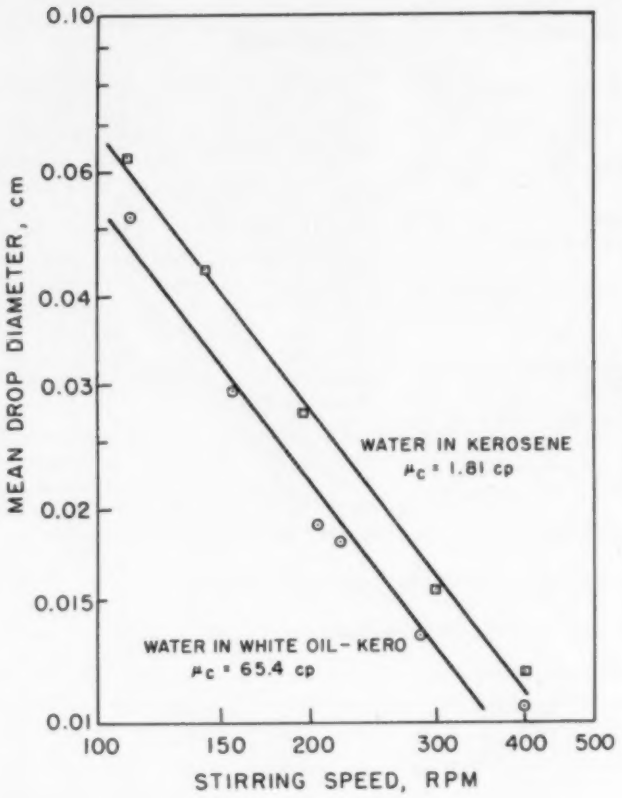


Fig. 8a. Effect of continuous-phase viscosity.

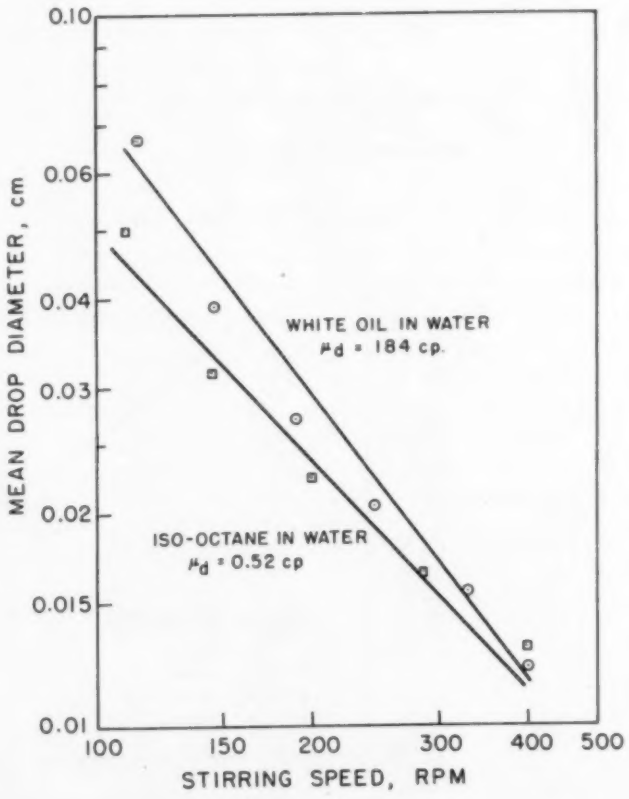


Fig. 8b. Effect of dispersed-phase viscosity.

eter varied by as much as 30%. Although the results in this form are only indicative, the conclusion will be drawn later that viscosity is without effect on liquid-liquid behavior.

For the air-liquid mixtures, by contrast, the liquid-phase viscosity appears to have a small effect. Runs with ethylene glycol ($\mu = 19.9$ centipoises) and diethylene glycol (36.5 centipoises) had bubble diameters two to three times those in the less viscous liquids studied. The correlation to be described later is based upon the relation

$$d = (\text{const.})\ \mu_C^{.25} \qquad (5)$$

The effect of discontinuous-phase viscosity is inconclusive for gases, because the gases used (air, helium, and, in exploratory runs, Freon 12) had closely similar values. However, the large difference between gas-liquid and liquid-liquid behavior should be attributed to either viscosity or density effects (or both) in the discontinuous phase; empirically, as will be seen, viscosity is a more likely cause.

Density, Density Difference

In the liquid-liquid runs no dependence of mean drop diameter upon density difference was observed, although $\Delta\rho$ was varied from 0.03 to 0.60. It appears that drag effects, which may be due to density differences, are not important in producing break-up of droplets within the range of density differences encountered.

The effect of gas-phase density was studied by a run with helium (saturated with CCl_4 vapor) as the dispersed phase in CCl_4. Results are shown in Figure 6; Runs 2 and 3 with air were made the same day, immediately before and after the run with helium. That the discontinuous-phase density does not have an appreciable effect is the conclusion.

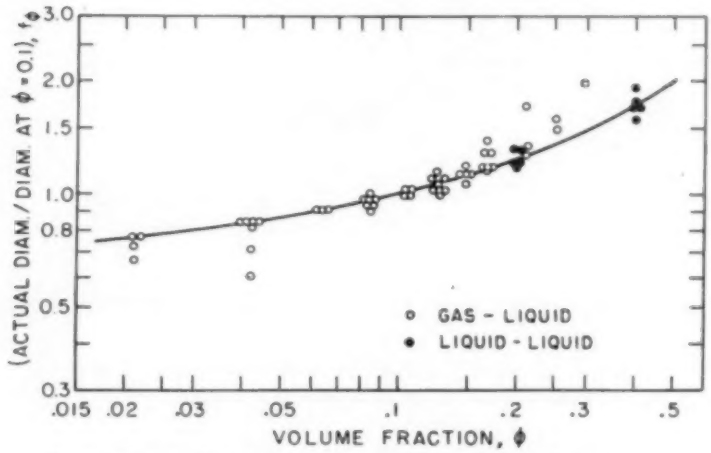


Fig. 9. Effect of volume fraction upon mean drop or bubble diameter.

Table 5.—Effect of Volume Fraction in Liquid-Liquid Mixtures

$d/d_{.1} = f_\phi$

Dispersed Phase	Continuous Phase	N rev./sec.	$\phi = 0.2$ Ratio	$\phi = 0.2$ Avg.	$\phi = 0.4$ Ratio	$\phi = 0.4$ Avg.
CCl_4	Water	3.00	1.18		1.57	
		4.50	1.22		1.56	
		6.00	1.22	(1.21)	1.67	(1.60)
Isooctane	Water	3.00	1.19		1.70	
		4.50	1.22		1.77	
		6.00	1.24	(1.22)	1.86	(1.78)
Water	Kerosene	3.00	1.20		1.31	
		4.50	1.36		1.82	
		6.00	1.41	(1.32)	2.06	(1.73)
		*1.58	1.08		1.38	
		2.58	1.20		1.85	
		3.27	1.30	(1.19)	2.00	(1.74)
Water	Blend C	3.00	1.37		1.95	
		4.50	1.31		1.88	
		6.00	1.33	(1.34)	2.00	(1.94)

* Runs in large tank.

Volume Fraction of Dispersed Phase

The mean diameter was found to depend upon the volume fraction ϕ of the dispersed phase, and became smaller as ϕ decreased. Data at each constant volume fraction were cross-plotted against speed to obtain the most probable diameter at certain representative speeds. At each speed these values were then plotted as a function of volume fraction to obtain the diameter at ϕ of 0.1 ($d = d_{.1}$). At each speed, also, the ratio of $d/d_{.1}$ was then calculated for each volume fraction.

These values are shown in Tables 5 and 6,* and are plotted in Figure 9. Although a large variation in behavior is shown for individual systems, it appears to be completely random, and the liquid-liquid and gas-liquid data are seen to be in substantial agreement. The curve is supported by additional data taken with other impellers. It may be used as an empirical function f_ϕ to account for variations in volume fraction; f_ϕ varies linearly with ϕ.

Slight effects of mean viscosity or mean density, which also depend on ϕ, do not upset the behavior shown in Figure 9.

The effect of this dependence is for the specific area to increase with increasing volume fraction, but to much less than a proportional extent due to the offsetting influence of increased particle size.

THEORETICAL CONSIDERATIONS

The steady-state dispersion obtained in mixing is possibly due to dynamic equilibrium between the splitting of droplets or bubbles and their coalescence into larger aggregates. It has not been possible to postulate any one simple mechanism that would explain the observed drop diameters. The following combination of effects is considered a likely means of producing the observed break-up

1. Initial elongation of a spherical drop due to acceleration upon its entrance into the high-velocity region of the tank in the vicinity of the impeller. Under the restoring effect of the interfacial forces the drop begins to oscillate.
2. Antidamping of the oscillation due to turbulent pressure variations. Clay (3) has proposed turbulence as the primary cause of bursting.
3. Production of surface waves by the turbulence in order to permit break-up into two particles of unequal size (so as to utilize a relatively small increase in the interfacial area).

* See footnote, page 85F.

Step 1 or 2, alone, each leads to a dependence of (d/L) upon Weber number ($We = N^2L^3\rho'/\sigma$), as is found empirically for the data. Here L is the impeller diameter; ρ' is an effective density ($0.6\rho_D + 0.4\rho_C$), as inferred from the limiting situations given by Lamb (*9*); ρ_D and ρ_C apply to the dispersed and the continuous phases respectively; and σ is the interfacial tension. Step 1 is consistent with (d/L) proportional to $(We)^{-.5}$; step 2, with (d/L) proportional to $(We)^{-1}$, as given by Clay. The dependence actually found is intermediate, proportional to $(We)^{-.6}$ as discussed below. Moreover, the drop diameter seems to be much smaller than could be accounted for either by elongation alone or by a single pressure fluctuation.

Taylor (*20*) has analyzed the behavior of unstable emulsions under laminar-flow conditions and has evaluated the pressure differences across drop boundaries that arise from surface forces and viscous forces jointly. His analysis also leads to (d/L) proportional to σ, and hence to $(We)^{-1}$, as a criterion for droplet stability. A more directly applicable result is his equation for the effective viscosity of an emulsion

$$\mu_m = \mu_C\left(1 + \phi\frac{\mu_C + 2.5\ \mu_D}{\mu_C + \mu_D}\right) \qquad (6)$$

Since this equation was derived for dilute suspensions, it should be extended along the lines of Robinson's results (*18*) for suspended solids to give the approximate relation

$$\mu_m = \frac{\mu_C}{1-\phi}\left[1 + \phi\ \cdot\ \frac{1.5\ \mu_D}{\mu_C + \mu_D}\right] \qquad (7)$$

This result signifies that the viscosity of an emulsion is closely related to the viscosity of the continuous phase; it is never less and increases with increasing volume fraction. Equation (*7*) represents the physical situation much more accurately than the logarithmically weighted viscosity used by several investigators (*15, 16*).

DIMENSIONLESS CORRELATION OF DATA

In the absence of a more explicit theoretical treatment the data have been analyzed for dimensionless correlation. It appears that the following independent groups could be involved:

1. Weber number, $We = N^2L^3\rho'/\sigma$.
2. Reynolds number, $Re = NL(T-L)\rho_m/\mu_m$.
3. Power number, $P_o = Pg_C/N^3L^4W\rho_m$.
4. Euler number involving compressibility, $NL(K_m\rho)^{1/2}$.
5. Froude number, $Fr = N^2L/g$; the acceleration number (8) which is related will probably reduce to a length ratio L/d.

In these relations W is the impeller width; T is tank diameter; P is power; and ρ_m is the bulk-mean density, $\rho_C(1-\phi) + \rho_D\phi$. The following additional ratios may be involved:

6. Volume fraction ϕ, which has already been found to enter through the function f_ϕ.
7. Viscosity ratios μ_C/μ_m, μ_D/μ_C, etc.
8. Density ratios ρ'/ρ_C, ρ_m/ρ_C, ρ_D/ρ_C, $\Delta\rho/\rho_m$, etc.
9. Length ratios dL, $(T-L)/L$, L/W, L^3W/T^2H (with H the height of the tank), etc.
10. Compressibility ratios K_D/K_C, K_m/K_C (with K_m the bulk-mean value, $K_c(1-\phi+K_D\phi)$.

Of these groups, 1, 2, 6, 7, 8 and 9 have been used in the present correlations. In the course of the investigation it appeared that the higher compressibility of the gas-liquid mixtures could explain their larger particle diameters. However, the introduction of K_m rendered it more difficult to correlate the separate gas-liquid and liquid-liquid regions.

The procedure finally followed was to develop dimensionless correlations for each of these regions. These were found to be closely similar and enabled an arbitrary combination to be made which would apply to both regions.

Liquid-Liquid Systems

An experimental dependence of d upon σ has been noted, along with the theoretical importance of the Weber number. To confirm the d vs. N relation noted earlier, the ratio $d/f_\phi L$ ($= d_{.1}/L$) was plotted against the group $N^2L^3\rho'/\sigma$, with the results of a -0.6 slope as shown in Figure 10. It is noted that L was constant for most of the runs, and the deviation of the large tank points is not considered significant.

Although the mean deviation is about 20%, no improvement was found when other groups listed above were tried in conjunction with these two. Specifically the possible effect of Re (or, for simplicity, $Re_C = NL^2\rho_C/\mu_C$) was tested by plotting it against the composite group $N^2d^{5/3}L^{4/3}\rho'/\sigma$; values for these latter two groups are also shown in Table 2. No trend was detected.

Thus the minimum values of mean drop diameter are expressed by the relation

$$\frac{N^2d^{5/3}L^{4/3}\rho'}{\sigma f_\phi^{5/3}} = 0.016 \qquad (8)$$

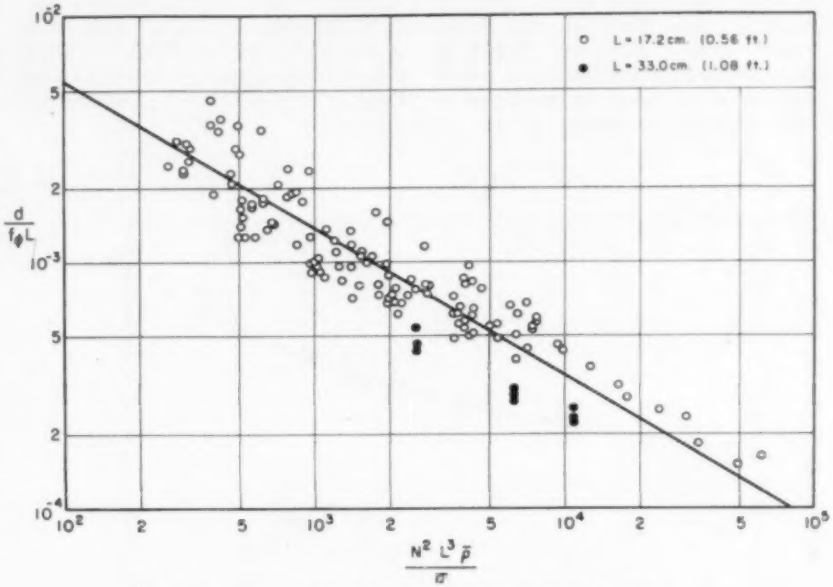


Fig. 10. Weber-number dependence of mean drop diameter.

The specific area (in the neighborhood of the impeller tip) is then expressed as

$$A = \frac{72N^{1.2}L^{.8}\rho'^{.6}\phi}{\sigma^{.6}\phi} \qquad (9)$$

in consistent units.

Gas-Liquid Systems

The effects of N and σ on d are qualitatively similar to those in the liquid-liquid systems, but the Weber number alone was found to give a wide scatter of points. The composite group $N^2d^{5/3}L^{4/3}\rho'/\sigma$ (used above) was plotted against various other groups and ratios, including Re. Finally a ratio of Reynolds to Weber groups was found,

$$\frac{d\sigma\rho_C}{\mu_D^2}\ \cdot\ \frac{\mu_C}{\mu_D}$$

which gives the desired relation of d to N and μ_C, when introduced to the

⅓ power. With $\rho = 0.4\rho_C$ the resulting equation is

$$\frac{N^{1.5}dL\rho_C^{.5}\mu_D^{.75}}{\sigma f_\phi \mu_C^{.25}} = 4.3 \times 10^{-3} \qquad (10)$$

From this relation the specific area is given by

$$A = \frac{1400\ N^{1.5}L\rho_C^{.5}\mu_D^{.75}\phi}{\sigma\mu_C^{.25}f_\phi} \qquad (11)$$

The correctness of the $N^{1.5}d$ relation is demonstrated by a cross-plot of $d/f_\phi L$ against a composite group which no longer contains d/f_ϕ, as plotted in Figure 1.

Interrelation of Two Types of Systems

The relations for gas and for liquid dispersions have been combined in order to insure that they are mutually consistent. Figure 12 shows a plot of $N^2d^{5/3}L^{4/3}\rho'/\sigma$ as ordinate against $(d\sigma\rho_C\mu_C)^{1/3}/\mu_D$ as abscissa, in which the liquid-liquid range gives a constant value of the ordinate, and gas-liquid range a +1 slope. The curve shown conforms to the equation

$$\frac{N^2d^{5/3}L^{4/3}\rho'/\sigma f_\phi^{5/3}}{[1 + 5.4 \times 10^{-6}d\sigma\rho_C\mu_C/f_\phi\mu_D^2]^{1/3}} = 0.016 \qquad (12)$$

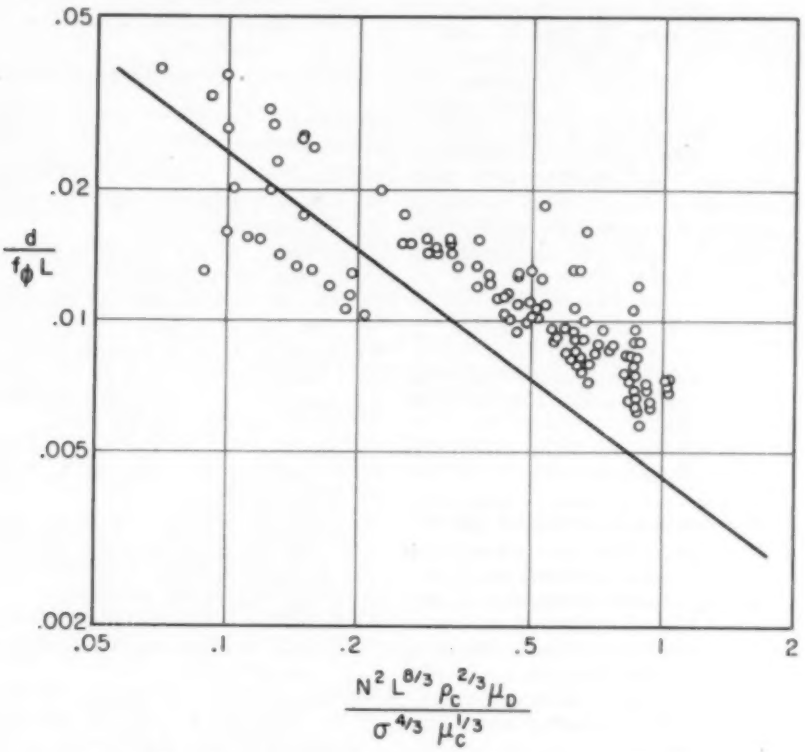


Fig. 11. Dimensionless representation for mean bubble diameter.

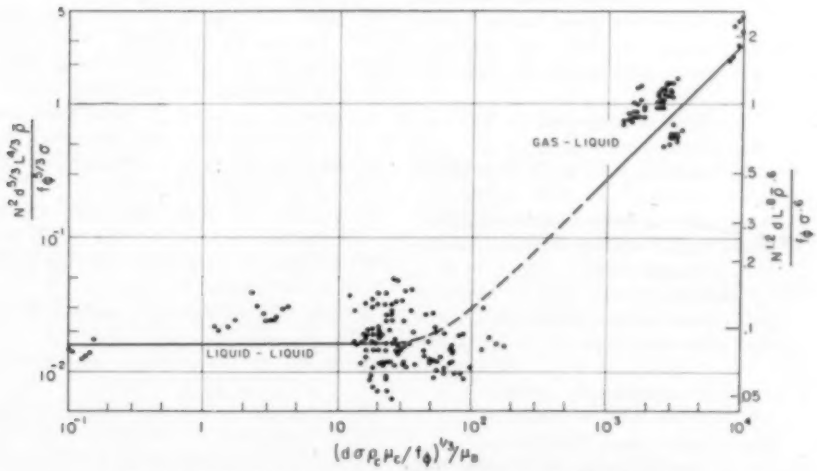


Fig. 12. Dimensionless correlation of mean drop or bubble diameter.

which contains the results of Equations (8) and (11). This is only one of several ways of combining the separate relations, and the optimum way will probably need to be determined by theoretical derivation.

Applications to Mass Transfer and Kinetics

As in other mass-transfer operations, the over-all transfer or reaction may be subdivided into individual steps. The slower any one step of the series is, the greater its effect in retarding the net rate of the over-all process. If one step is relatively very slow, it is said to be rate controlling. The following steps appear to be involved

1. mass transfer on the continuous-phase side of the interface.
2. chemical reaction at the interface or mass transfer through it.
3. mass transfer on the dispersed-phase side of the interface.

The dependence of interfacial area upon mixing conditions, as just established, will be used to predict the dependence of transfer kinetics upon mixing under conditions where the rate is controlled by each of the listed steps.

process control

CONTINUOUS-PHASE RESISTANCE CONTROLLING

This case should be most directly comparable to that of mass transfer between a liquid and a suspended solid, for which Hixson and Baum (*7*) and Mack and Marriner (*14*) have suggested relations which for systems of constant geometry may be put into the following form:

$$\frac{kL}{D''} = C\left(\frac{NL^2\rho_C}{\mu_C}\right)^{.6}\left(\frac{\mu_C}{\rho_C D''}\right)^{.5} \qquad (13)$$

where C is a numerical constant (0.16 in their work), and D'' is the applicable diffusivity. Combination of this relation with Equation (10) for liquid-liquid systems will give the rate coefficient (kA) in consistent units of reciprocal time as

$$kA = \frac{72CN^{1.8}LD''^{.5}\phi}{(\sigma/\rho')^{.6}(\mu_C/\rho_C)^{.1}f_\phi} \qquad (14)$$

Though the precise effects of impeller, baffle, and tank dimensions are not yet determined, it is of interest to calculate the magnitude of the rate coefficient. With $C = 0.16$, $N = 4$ rev./sec., $L = 17.2$ cm., $D'' = 1.0 \times 10^{-5}$ sq.cm./sec., $\mu_C/\rho_C = 10^{-2}$ sq.cm./sec., $\sigma/\rho = 50$ cc./sq.sec. and $\phi = 0.1$, the calculated value of kA is 0.11 sec. In a laboratory-

scale tank, this would correspond to a half-life of $0.693/0.11 = 6.3$ sec. for the transfer operation.

Because the interfacial conditions around a liquid droplet are not identical with those around a solid particle, this value is only approximate. However, exploratory rate studies under continuous-flow conditions in the present mixing tanks have indicated that equilibrium is approached in a matter of seconds, so rapidly in fact that representative rates could not be measured. This confirms industrial experience that satisfactory mass transfer between low-viscosity liquids can often be obtained with mixing equipment that is simpler and provides shorter residence time than the stirred tank.

Gas-liquid mixing in stirred tanks is of current industrial importance, particularly in fermentation processes. The larger bubble sizes, and the small gas holdup normally obtained indicate that mass transfer will be slower than in the usual liquid-liquid case. Combination of Equations (11) and (13) for gas-liquid mixtures gives

$$kA = \frac{(1400\ C)N^{2.1}L^{1.2}\rho_C{}^{.6}\mu_D{}^{.75}D''^{.5}\phi}{\sigma\mu_C{}^{.35}f_\phi} \qquad (15)$$

The numerical coefficient $(1400\ C)$ is on the order of 220, but is subject to the uncertainty already discussed.

DISPERSED-PHASE RESISTANCE CONTROLLING

A theoretical treatment of this case results in a complicated series function (*1, 17*). However, it can be approximated by a linear driving potential (*21*) with the result that

$$kA = \frac{4\pi^2 D''}{d^2} \qquad (16)$$

Substituting a value of $d = 10^{-2}$ cm., and $D'' = 10^{-5}$ sq.cm./sec., $kA \sim 4$ sec^{-1} for a typical low-viscosity liquid. Similarly, with $d = 10^{-1}$ cm. and $D'' = 10^{-1}$ sq.cm./sec. for gases, $kA \sim 400$ sec^{-1}. These already high values will be increased by distortion and oscillation in the vicinity of the impeller by coalescence and break-up of the droplets or bubbles, and often by internal circulation (*8*).

INTERFACIAL REACTION (OR DIFFUSION THROUGH THE INTERFACE) CONTROLLING

Heterogeneous reactions have been reported in which the rate increases with stirring speed without observable limit. Reaction at the interface should of course be proportional to the extent of interfacial area, i.e., to the 1.2 power of speed for liquid-liquid systems and to the 1.5 power of speed for gas-liquid systems.

HOMOGENEOUS REACTION RATE CONTROLLING

This situation can be identified by a transition from increasing rate to constant rate as agitation intensity increases. When the reaction itself is relatively slow, physical equilibrium between phases may be approached closely, so that the rate no longer depends upon mass-transfer conditions. However, the observed rate for such reactions will be proportional to the volume fraction of the phase in which reaction occurs.

Acknowledgment

The authors wish to express their thanks to Homer E. Rea, Jr., and J. Leonard Fick of the University of California Radiation Laboratory for computational work and confirmatory experiments relating to this study; to Fred L. Toby, also of the Radiation Laboratory, for design of the large tank used in several runs; to Morris Eisenberg, for helpful discussions; and to Edith P. Taylor, for preparation of the final manuscript.

Notation

A = specific area, or total interfacial area per unit volume, sq.cm./cc. (or sq. ft./cu.ft.)
d = mean drop or bubble diameter [see Equation (2)]
$d_{.1}$ = value of d at volume fraction $\phi = 0.1$
D'' = diffusivity, sq.cm./sec. (or sq.ft./hr.)
f_ϕ = ratio of actual mean drop or bubble diameter to diameter at $\phi = 0.1$
g = gravitational acceleration, cm./(sec.)(sec.)[or ft./(hr.)(hr.)]
g_c = gravitational conversion factor, g. cm./(sec.)(sec.) dyne (or ft.lb. mass/(hr.)(hr.)(lb. force)
H = height of liquid-filled tank, cm. (or ft.)
I = light transmission through the emulsion, lumens/sq.cm.
I_o = light transmission through clear fluid (continuous phase alone), lumens/sq.cm.
k = mass-transfer coefficient, cm./sec. (or ft./hr.)
L = paddle diameter, cm. (or ft.)
m = refractive index ratio, n_D/n_C
n_C = refractive index (n_D^{25}) of continuous phase
n_D = refractive index of dispersed phase
N = angular velocity of stirrer, rev./sec. (or rev./min.)
P = power
P_c = power number, Pg_c/N^3L^4W
Re = Reynolds number for a stirred tank, $NL^2\rho_m/\mu_m$
T = tank diameter, cm. (or ft.)
W = paddle width, cm. (or ft.)
We = Weber group, $N^2L^3\rho'/\sigma$
β = slope of curves of extinction ratio (I_o/I) against specific area; see Equation (1)
K = compressibility, sq.cm./dyne (or sq. ft./lb. f.); K_m is mean compressibility for a mixture, $(1-\phi)K_C + \phi K_D$
μ_C = viscosity of continuous phase, g./(sec.)(cm.) (or lb./(hr.)(ft.)
μ_D = viscosity of dispersed phase
μ_m = viscosity of emulsified mixture [see Equation (7)]
ρ_C = density of continuous phase, g./cc. (or lb./cu.ft.)
ρ_D = density of discontinuous phase
ρ_m = volume-fraction mean density, $(1-\phi)\rho_C + \phi\rho_D$
ρ' = effective mean density; $0.6\rho_d + 0.4\rho_C$
$\Delta\rho$ = density difference, $|\rho_C - \rho_D|$
σ = interfacial tension, dynes/cm. or lb. mass/(hr.)(hr.)
ϕ = volume fraction of dispersed phase

Literature Cited

1. Barrer, R. M., "Diffusion In and Through Solids," University Press, Cambridge, England, p. 29 (1941).
2. Bromley, L. A., and C. R. Wilke, *Ind. Eng. Chem.*, **43**, 1641 (1951).
3. Clay, P. C., *Proc. Acad. Sci. Amsterdam*, **43**, 852, 979 (1940).
4. Cooper, C. M., G. A. Fernstrom, and S. A. Miller, *Ind. Eng. Chem.*, **36**, 504 (1944).
5. Foust, H. C., D. E. Mack, and J. H. Rushton, *Ind. Eng. Chem.*, **36**, 517 (1944).
6. Hixson, A. W., and S. J. Baum, *Ind. Eng. Chem.*, **33**, 478 (1941); **34**, 194 (1942); **36**, 528 (1944).
7. Hixson, A. W., and A. H. Tenney, *Trans. Am. Inst. Chem. Engrs.*, **31**, 113 (1935).
8. Hughes, R. R., and E. R. Gilliland, *Chem. Eng. Progress*, **48**, 497 (1952).
9. Lamb, H., "Hydrodynamics," University Press, Cambridge, England, especially pp. 474-475 (1932).
10. Langlois, G. E., J. E. Gullberg, and T. Vermeulen, *Rev. Sci. Instrs.*, **25**, 360 (1954).
11. Long, R. S., M.S. thesis in chemical engineering, University of California (1949).
12. MacDonald, R. W., and E. L. Piret, *Chem. Eng. Progress*, **47**, 363 (1951).
13. Mack, D. E., and A. E. Kroll, *Chem. Eng. Progress*, **44**, 189 (1948).
14. Mack, D. E., and R. A. Marriner, *Chem. Eng. Progress*, **45**, 545 (1949).
15. Miller, S. A., and C. A. Mann, *Trans. Am. Inst. Chem. Engrs.*, **40**, 709 (1944).
16. Olney, R. B., and G. J. Carlson, *Chem. Eng. Progress*, **43**, 473 (1947).
17. Paterson, A., *Proc. Phys. Soc.*, **59**, 50 (1947).
18. Robinson, J. V., *J. Phys. Coll. Chem.*, **53**, 1042 (1949).
19. Rushton, J. H., *Chem. Eng. Progress*, **48**, 33, 95 (1952).
20. Taylor, G. I., *Proc. Roy. Soc. (London)*, **A138**, 41 (1932).
21. Vermeulen, T., *Ind. Eng. Chem.*, **45**, 1664 (1953).

Presented in part at A.I.Ch.E. Chicago meeting.

Because of the limitations of the ideal mixture K-values, particularly at high

hydrocarbon systems in such a way as to simulate all possible mixtures of the twelve

combined into a generalized correlation using reduced temperature and pressure and

generalized activity coefficients of hydrocarbon mixture components

Wayne C. Edmister and Charles L. Ruby

California Research Corporation, Richmond, California

Hydrocarbon processing calculations deal with mixtures for which phase equilibria and energy balance calculations must be made. Some of these hydrocarbon systems behave ideally and so their properties in the mixture can be computed from the properties of the pure components. For most mixtures, however, this ideal situation does not hold and so it is necessary to have data that take this nonideal behavior into consideration.

Because vapor-liquid equilibria and energy balance calculations are generally made for the same system and the same conditions, it is important that the data employed for each calculation be consistent with those used for the other. For calculations of this kind it is necessary to have fugacity and enthalpy values that can be applied to each of the components for computing the phase compositions and enthalpies.

Fugacities, partial volumes, partial entropies, and partial enthalpies are related. The actual values of these thermodynamic properties for each hydrocarbon depend upon the temperature and pressure conditions and upon the system composition. For multicomponent systems this can be very complicated; therefore it is desirable to simplify with short cuts which give reasonably accurate results.

In the past such simplifications have not always been adequate, and so the results of processing calculations based upon them have not been sufficiently accurate. Before 1932 the vapor-liquid equilibria phase distribution calculations for hydrocarbon systems were frequently made by the use of vapor pressures, and heat balances were made by the use of average heat capacities for liquid and vapor and approximate heats of vaporization for the mixture. During the past twenty years the thermodynamic tools for such process engineering calculations have been improving gradually, and now methods are available for estimating the temperature, pressure, and composition effects on the vapor-liquid equilibria and the enthalpy for hydrocarbon systems.

The object of the work reported herein was to develop a generalized correlation of the activity coefficients of components in hydrocarbon vapor and liquid mixtures. Such a correlation would permit the extension of phase equilibria estimates to other components and conditions and the calculation of consistent values for the other partial thermodynamic properties.

Activity Coefficients and K-Values

Coexisting liquid and vapor phases are in equilibrium when the pressure and temperature of the two phases are equal and when the fugacity values of each component are the same in each phase, i.e., $f'^L = f'^V$. Component designating subscripts will be omitted from the equations for simplicity.

The K-value of each component is defined as the ratio of the mole fraction of that component in the vapor phase to the mole fraction in the liquid phase, i.e., $K = y/x$. In terms of fugacity coefficients, i.e., ratio of fugacity to mole fraction, the K-value is

$$K = \frac{y}{x} = \frac{f'^L/x}{f'^V/y} \qquad (1)$$

The fugacity coefficients, which have the dimensions of pressure, can be calculated from pressure-volume-temperature-composition data on mixtures by the application of thermodynamic relations and an equation of state. Experimental vapor-liquid equilibria measurements give values of y and x and not fugacity coefficients.

For correlation purposes Equation 1 can be written

$$K = \frac{y}{x} = \left(\frac{f'^L/P^\circ x}{f'^V/Py}\right)\left(\frac{P^\circ}{P}\right) \qquad (2)$$

where

P° = vapor pressure of any component at system temperature
P = total pressure
P°/P = Raoult's law K-value
$f'^L/P^\circ x$ = activity coefficient of any component in liquid phase
f'^V/Py = activity coefficient of any component in vapor phase

The denominators of these two activity coefficients are the standard states of reference. At system temperatures above the critical, an extrapolated vapor pressure must be used. Thus the standard state for the vapor is the partial pressure of the component in the vapor phase (Dalton's law) and the standard state for the liquid is the partial vapor pressure (Raoult's law).

This choice of standard state is justified by the resulting correlation. It is logical and convenient because the ratio of these activity coefficients is a correction to the simple Raoult's law K-value.

Previous Correlations

Generalized correlations of thermodynamic properties have been useful chemical engineering tools for the past two decades. By using reduced pressures (P/P_c) and temperatures (T/T_c), pressure-volume-temperature (P-V-T) data for pure hydrocarbon systems have been correlated. From these generalized compressibility factor and residual volume correlations, the isothermal effects of pressure on the enthalpy and entropy and the activity coefficients were derived for pure component systems (*10, 11, 12, 20, 25, 26, 40*).

These pure component generalized correlations have been applied to mixtures by two convenient concepts. The Lewis and Randall fugacity rule (*24*), which is based on Amagat's law of additive volumes, has been used to estimate the fugacity of hydrocarbons in mixtures from the "pure component" generalized f/P correlation (*25, 26, 40*). The M.I.T. hydrocarbon K-value plots, which correct for deviations from perfect gas laws but not ideal solutions, were prepared in this way.

calculator. Typewritten tapes giving the f/Py and f/x values and the correspond-

from the cards containing these results. These were later used in checking the

Vapor pressures were required over a wide range of temperatures for con-

Because of the limitations of the ideal mixture K-values, particularly at high pressures, several empirical correlations of experimental data have been prepared (*13, 14, 19, 28, 29, 36, 42*). The convergence pressure has been proposed (*19*) as a method of forcing the K-values to converge at unity. Although the convergence pressure technique has been useful in K-value predictions, it does not reflect the individual effects of separate phase composition and does not help solve the companion partial thermodynamic properties problem.

Kay's pseudocritical concept (*20*) has been used to estimate compressibility factors and some other thermodynamic properties from the corresponding pure component generalized correlations. Vapor phase activity coefficient computations have been based on this pseudocritical concept.

From these developments, generalized correlations of vapor phase and liquid phase activity coefficients were prepared by Smith and Watson (*39*). Their vapor phase correlations were developed from generalized pure component properties and the pseudocritical conditions, whereas their liquid phase correlations were derived from the resulting vapor phase correlations and experimental K-values. In this method of calculating activity coefficients, the deficiencies of the three pure component generalized correlations, the pseudocritical concept, and the experimental data used in the development could accumulate.

The simultaneous estimation of K-values and thermodynamic properties requires the use of more basic thermodynamic methods, such as an empirical equation of state fitted to experimental pressure-volume-temperature-composition data and then applied to the computations of the thermodynamic properties. Because these properties are related, fugacities or activity coefficients can be computed first and the others obtained from the fugacities.

Benedict et al. (*2*) developed such an empirical equation of state and computed vapor activity and liquid fugacity coefficients for twelve light hydrocarbons under pressure up to 3600 lb./sq.in.

Because of the large number of composition possibilities presented by twelve components, these authors selected molal average boiling point of the phase in question as the composition variable. This was admitted to be a compromise between precision and practicality, but the results would have been unwieldy otherwise. With this simplification, several series of fugacity calculations were made for selected binary hydrocarbon systems in such a way as to simulate all possible mixtures of the twelve hydrocarbons. By the selection of binary systems, the assumption was made that the balance of the mixture, other than the component in question, could be treated as a single average hypothetical component. This is an approximation which was justified by the results.

After calculation of these binary system fugacity coefficients, the results were correlated as a function of temperature, pressure, and molal average boiling point of the phase in question. Thus, composition effect was handled by the average boiling point of the phase, an empirical approximation limited to the paraffinic and olefinic hydrocarbon systems covered.

The charts resulting from this work were prepared in 1942 (*22*) and were replotted and published by The M. W. Kellogg Company in 1950 (*23*). Publication was in two parts, one containing 144 charts of K-values with correction factors for pressures up to 1000 lb./sq.in. and the other containing 132 charts of fugacity coefficients for pressures from 1000 to 3600 lb./sq.in.

Recently the atmospheric to 1000 lb./sq.in. Kellogg charts were replotted and improved by De Priester (*8*) with three objectives: (a) to reduce the number of charts required, (b) to facilitate pressure interpolations, and (c) to improve the accuracy in some ranges. These latest pressure - temperature - composition charts are in the form of two-parameter charts for each hydrocarbon, one for the liquid phase and one for the vapor phase; thus 144 charts are condensed to 24 with improved accuracy. Additional experimental K data were used in the preparation of these charts.

In a parallel and independent project Canjar and Edmister (*5*) computed partial enthalpy values for six light hydrocarbons from the first temperature derivatives of the fugacity and activity coefficients from the original Polyco charts (*22*). The partial enthalpy differences thus obtained were combined into a generalized correlation using reduced temperature and pressure and boiling point ratio as the parameters.

Boiling point ratio, which is the parameter that handled the composition effect, is the ratio of the molal average atmospheric boiling point of the phase to the atmospheric boiling point of the component. Thus, this ratio, like the reduced temperature and pressure, has a system property in the numerator and a component property in the denominator.

The three reduced parameters found successful in this generalized partial enthalpy correlation are

$$T_{ri} = \frac{T}{T_{ci}} = \frac{\text{System temperature, } ^\circ\text{R.}}{\text{Critical temperature of } i\text{th component, } ^\circ\text{R.}}$$

$$P_{ri} = \frac{P}{P_{ci}} = \frac{\text{System pressure, lb./sq.in.abs.}}{\text{Critical pressure of } i\text{th component, lb./sq.in.abs.}}$$

$$B_{ri} = \frac{B}{B_i} = \frac{M.A.B.P. \text{ of vapor or liquid-phase mixture, } ^\circ\text{R.}}{\text{Atmospheric boiling point of } i\text{th component, } ^\circ\text{R.}}$$

For any set of equilibrium conditions, the first two ratios will be the same in both liquid and vapor phase for any component, whereas the third will differ for the two phases.

The subscript i will be omitted from all equations that follow. When T_r, P_r, and B_r appear, they apply to each component of the mixture. The value of B_r will range from less than unity to greater than unity for each phase. $B_r = 1.0$ for a pure (or single) component system. B_r is also unity for the component having a boiling point equal to the molal average boiling point of the mixture.

These parameters were used in developing the generalized activity coefficient correlations.

Data for Correlations

From the original Polyco (*22*) charts of the Benedict et al. (*2*) work, smoothed values of f/x and f/Py (Note: Benedict et al. used the symbol f without the bar above and the superscript V or L to designate fugacity in vapor or liquid mixtures.) were read and the parameters converted to reduced units. Two-way interpolations were then made to get values of f/x and f/Py at even 0.1 intervals of T_r and B_r. This was done as described below.

A total of 31,000 points was taken for the two phases of the twelve hydrocarbons (methane, ethylene, ethane, propylene, propane, isobutylene, isobutane, n-butane, isopentane, n-pentane, n-hexane, and n-heptane) at eleven of the eighteen pressures (50, 200, 400, 600, 800, 1000, 1400, 1800, 2200, 2800, and 3600 lb./sq.in.) and eleven of the sixteen molal average boiling points (−255, −240, −210, −150, −60, 0, +60, 120, 150, and 180° F.) for which plots were available. Readings were made at 20° F. system temperature intervals to facilitate interpolations.

These data were punched on *IBM* cards from which reduced conditions (i.e., T_r, P_r, and B_r) were computed on a wire-programmed *IBM* Model 602A

°F	CH_4	C_2H_4	C_2H_6	C_3H_6	C_3H_8	iC_4H_8	iC_4H_{10}	nC_4H_{10}	iC_5H_{12}	nC_5H_{12}	nC_6H_{14}	nC_7H_{16}
-100	866.6	65.33	31.31	3.853	2.887	0.388	0.547	0.276				
-80	1135	101.0	50.37	7.21	5.48	0.860	1.171	0.625				
-60	1451	149.5	77.29	12.55	9.68	1.739	2.295	1.285	0.296	0.179		
-40	1809	215.1	113.9	20.61	16.16	3.249	4.17	2.439	0.622	0.392		
-20	2212	294.3	161.8	31.94	25.30	5.684	7.12	4.326	1.205	0.789	0.15	
0	2657	395.1	223.2	47.64	38.11	9.404	11.53	7.25	2.182	1.475	0.311	
20	3143	517.5	299.7	68.76	55.46	14.90	17.86	11.56	3.726	2.594	0.606	
40	3668	663.3	393.0	96.32	78.30	22.34	26.41	17.69	6.05	4.325	1.107	0.288
60	4232	834.3	504.7	131.5	107.6	32.45	37.89	25.90	9.42	6.887	1.911	0.541
80	4829	1031	636.2	175.5	144.6	45.85	52.93	36.87	14.10	10.54	3.143	0.960
100	5461	1256	789.1	229.3	190.3	63.22	72.19	51.18	20.40	15.63	4.956	1.620
120	6120	1510	963.8	294.3	245.6	85.23	96.34	69.45	28.54	22.20	7.531	2.616
140	6810	1791	1162	371.3	311.6	112.7	126.2	92.37	39.04	30.82	11.075	4.065
160	7523	2102	1385	461.5	389.3	146.3	162.4	120.6	52.34	41.90	15.89	6.106
180	8260	2443	1631	565.9	479.7	186.8	205.7	154.8	67.35	55.88	21.93	8.899
200	9020	2813	1902	685.7	583.5	235.2	256.8	195.7	89.21	73.21	29.69	12.62
220	9797	3213	2199	821.2	702.0	291.8	316.6	244.2	113.7	94.43	39.49	17.45
240	10,590	3642	2521	973.4	835.4	358.0	385.6	300.7	143.0	120.0	51.69	23.47
260	11,400	4099	2868	1143	984.7	434.0	464.5	366.1	177.5	150.5	66.61	31.08
280	12,230	4583	3241	1330	1150	520.7	554.0	441.0	217.9	186.5	84.68	40.52
300	13,050	5097	3638	1537	1332	618.9	654.5	526.0	264.4	228.5	106.3	52.08
320	13,900	5635	4060	1761	1533	729.0	766.8	621.8	317.9	277.0	131.9	66.10
340	14,750	6200	4506	2005	1751	851.7	891.3	728.8	378.6	332.7	161.9	82.88
360	15,610	6790	4975	2269	1986	987.7	1028	847.7	447.1	395.8	196.8	102.8
380	16,470	7403	5469	2552	2241	1137	1179	979.0	523.7	467.3	237.0	126.3
400	17,340	8041	5984	2854	2513	1300	1342	1123	609.1	547.3	283.0	153.5

Table 1.—Values of P° for Liquid Phase Activity Coefficients lb./sq. in. abs.

Components	Pressure From	Pressure To	Temperature From	Temperature To	No. of Points	Source
			1. Binary systems			

calculator. Typewritten tapes giving the f/Py and f/x values and the corresponding reduced parameters were printed from the cards containing these results. These were later used in checking the precision of the correlations.

Two-way interpolations were next made to get values of f/x and f/Py at even 0.1 intervals of T_r and B_r. From this interpolation a total of about 3000 values (an average of 250 for each hydrocarbon) were obtained from the 31,000 original data points for the plotting work. These smoothed and interpolated f/x and f/Py values covered a wide range of T_r, P_r, and B_r conditions. At the higher B_r and T_r conditions, the data were mostly for the lighter hydrocarbons; whereas the data for the heavier hydrocarbons fell in the lower B_r and T_r ranges. There was enough overlapping, however, to test the adequacy of the generalization.

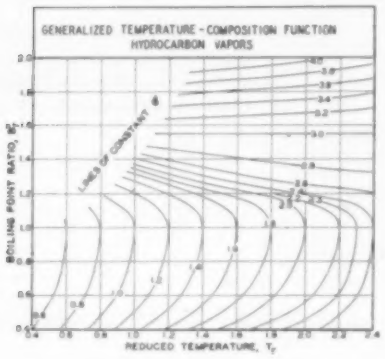


Fig. 1.

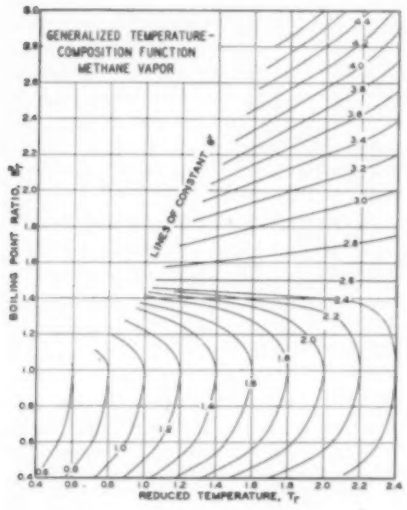


Fig. 2.

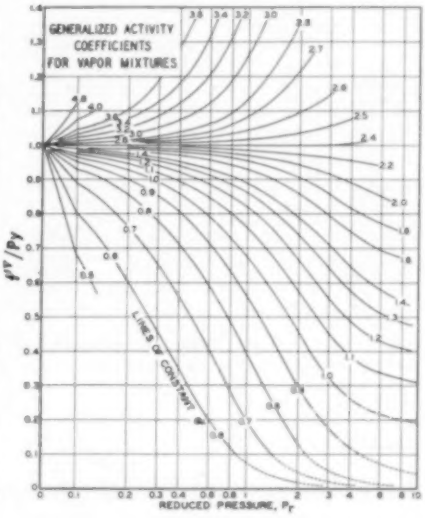


Fig. 3.

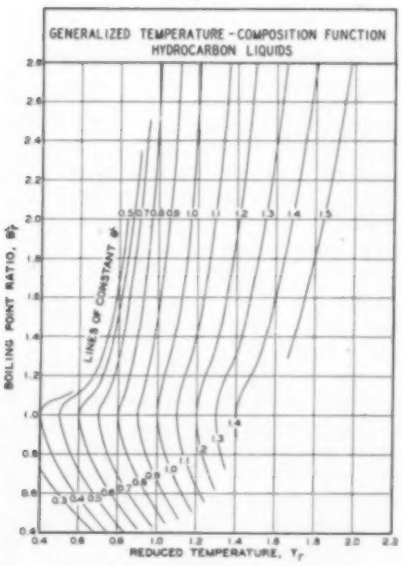


Fig. 4.

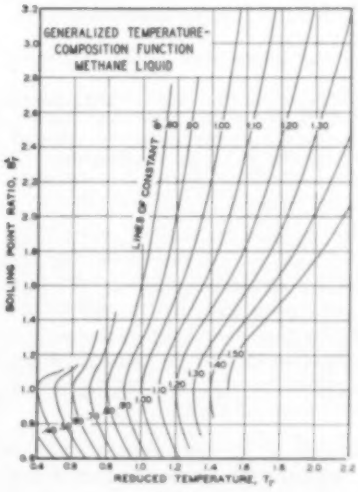


Fig. 5.

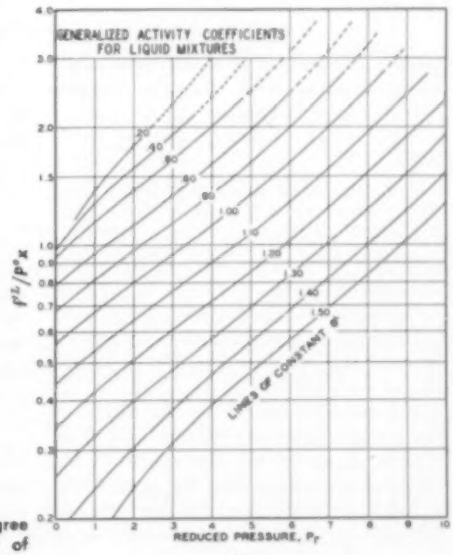


Fig. 6.

Large scale, detailed drawings of Figures 1-6, which can be read to a much higher degree of accuracy, are on file with A.D.I. Auxiliary Publications Photoduplication Service, Library of Congress, Washington, D. C.

Vapor pressures were required over a wide range of temperatures for converting the liquid fugacity coefficients (f/x) to activity coefficients ($f/P^o x$) for correlation development. Some of the temperatures of interest in this work fall below the boiling points of the heavier hydrocarbons, whereas others are above the critical points of the lighter components. Selected vapor pressure values are available below the atmospheric boiling point, but extrapolation is required to get values of P^o above the critical temperature.

The method used to get values of P^o was as follows: (a) use API Research Project 44 (*35*) vapor pressure values up to the atmospheric boiling point, and (b) use a straight line on log P vs. $1/T$ scales from the atmospheric boiling point through the critical point to get values above atmospheric boiling point. A straight line on log P vs. $1/T$ scales gives a logical and reproducible method of extrapolation to temperatures above the critical. The values of P^o obtained in this way and used in this correlation are given in Table 1.

Development of Correlations

Separate correlations were developed for each phase, giving the activity coefficients as functions of P_r, T_r, and B_r. This was done by plotting f/Py (and $f/P^o x$) against P_r for lines of constant T_r for each B_r value.

Hydrocarbon	Binary Systems		Multicomponent Systems				All Systems	
			De Priester		Other Data			
	Abs. Dev.	No. of Points	Abs. Dev.	No. of Points	Abs. Dev.	No. of Points	Abs. Dev.	No. of Points

Reduced conditions are next found from

Table 3. — Literature Data Sources of K-Values

Components	Pressure From	Pressure To	Temperature From	Temperature To	No. of Points	Source
			1. Binary Systems			
Methane	100	600	-201	+16	14	(4)
Ethane	100	600	-201	+16	11	
Ethane	100	500	0	225	6	(21)
n-Butane	100	500	0	225	6	
Ethane	200	800	275	350	2	(12)
n-Heptane	200	800	275	350	2	
Methane	200	700	100	220	6	(27)
i-Butane	200	700	100	220	6	
Methane	60	800	70	220	6	(37)
n-Butane	60	800	70	220	6	
Methane	20	800	100	340	5	(41)
n-Pentane	20	800	100	340	5	
n-Pentane	147	445	285	447	6	(7)
n-Heptane	147	445	285	447	6	
Propane	200	620	125	260	6	(38)
1-Butylene	200	620	125	260	6	
Methane	200	800	70	160	5	(32)
Propane	200	800	70	160	6	
Propylene	70	340	25.5	135	9	(16)
Propane	70	340	25.5	135	9	
Ethylene	57	255	-100	100	10	(17)
Ethane	57	255	-100	100	10	
			2. De Priester Multicomponent Systems			
Methane	100	800	-60	300	26	(8)
Ethane	100	800	-60	300	29	
Propane	100	800	-60	300	28	
i-Butane	100	800	-60	300	6	
n-Butane	100	800	-60	300	19	
n-Pentane	100	800	-60	300	7	
n-Heptane	100	800	-60	300	1	
2,2,4-Trimethylpentane	100	800	-60	300	1	
n-Decane	100	800	-60	300	1	
			3. Other Multicomponent Systems			
Methane	2055	3485	40	200	4	(34)
Ethane	2055	3485	40	200	4	
Propane	2055	3485	40	200	4	
Methane	500	1000	100	160	4	(1)
Ethylene	500	1000	100	160	4	
i-Butylene	500	1000	100	160	4	
Methane	500	1000	100		2	(3)
Ethane	500	1000	100		2	
n-Pentane	500	1000	100		2	
Methane	500	1000	100		2	(6)
Propane	500	1000	100		2	
n-Pentane	500	1000	100		2	
Methane	500	1000	160	220	4	(9)
Propane	500	1000	160	220	4	
n-Pentane	500	1000	160	220	4	
Methane	1000		160		1	(31)
n-Butane	1000		160		1	
n-Decone	1000		160		1	
Methane	1000		280		1	(33)
n-Butane	1000		280		1	
n-Decane	1000		280		1	
Methane	517	1736	100		4	(15)
Ethane	517	1736	100		4	
Propane	517	1736	100		4	
n-Butane	517	1736	100		4	
n-Pentane	517	1736	100		4	
Methane	1046	1419	100		2	(15)
Ethane	1046	1419	100		2	
Propane	1046	1419	100		2	
n-Pentane	1046	1419	100		0	
n-Hexane	1046	1419	100		1	

Table 3.—(Continued)

Hydrocarbon	Liquid Phase Abs. % Dev.	Liquid Phase No. of Points	Vapor Phase Abs. % Dev.	Vapor Phase No. of Points
Methane	5.0	67	2.1	97
Ethylene	3.0	78	2.6	125
Ethane	3.1	60	2.4	98
Propylene	3.8	40	1.8	58
Propane	3.2	40	2.2	73
i-Butylene	3.4	61	4.2	70
i-Butane	3.8	36	4.3	57
n-Butane	4.1	40	4.2	72
i-Pentane	4.2	62	4.9	60
n-Pentane	5.3	33	6.9	62
n-Hexane	5.2	55	7.5	60
n-Heptane	5.2	52	6.6	50
Totals	4.1	624	3.8	882

Table 2.—Deviations of Generalized Activity Coefficients from Benedict (Polyco) Values

The regularity and progression with B_r of these plots for each phase suggested the possibility of consolidation by means of an intermediate temperature-composition scale, θ, which is equal to T_r at $B_r = 1.0$. In this way, the activity coefficients become functions of P_r and θ, where θ is a separate function of T_r and B_r for each phase.

Figures 1, 2, and 3 are the charts of the vapor phase correlation, and Figures 4, 5, and 6 are the charts of the liquid phase correlation. Separate θ–T_r–B_r plots were required for methane, but the activity coefficient plots apply to all hydrocarbons.

The composite plots for each phase were developed in the following manner:

1. With the use of a light table the various B_r plots were superimposed upon the $B_r = 1.0$ plot at matching coordinates.
2. Values of B_r, θ(T_r at $B_r = 1.0$) and T_r for each B_r plot were tabulated and found to be essentially independent of reduced pressure.
3. These values were plotted as Figures 1, 2, 4, 5.
4. Regions of data not covered by the original $B_r = 1.0$ plot were then filled in by the use of values from the other B_r plots and the θ–T_r–B_r relationship. The final results were Figures 1 to 6 which cover the ranges of the Polyco data.

The two methane θ–T_r–B_r plots (Figures 2 and 5) were extended to B_r's below 1.0 by making use of the lines from the plots (Figures 1 and 4) prepared for the other hydrocarbons. This was done to extend the possible use of these plots to other systems and conditions.

Because θ is a common parameter of the temperature-composition and the activity coefficient plots, it would be possible to replot both charts with θ as one of the coordinates and then combine them to give a two-parameter representation, similar to the De Priester (*8*) plots. This was considered and discarded because of the fold over that would result on all except Figure 6.

Comparisons with Original Polyco Values

Table 2 presents a comparison between the generalized activity coefficient correlation and the original Polyco f/x and f/Py values. For the liquid phase the absolute average deviation was found to be 4.1% for 624 points, and for the vapor phase the absolute average deviation was found to be 3.8% for 882 points. This is equal to an over-all average for both phases of 3.9% for 1506 points.

The original Polyco fugacity charts contain uncertain and extrapolated or dashed-line regions. These regions have been indicated on the vapor phase chart (Figure 3) and the liquid phase chart (Figure 6) by dashed lines.

On Figure 3 the lines of constant θ^V converge to unity at $P_r = 0$. The θ^L lines on Figure 6 have not been drawn down to $P_r = 0$ as insufficient data were available to define the curves adequately in this low-pressure region.

Table 4.—Deviation of Proposed Generalized Activity Coefficient Correlation from Experimental *K*-Values

Hydrocarbon	Binary Systems		Multicomponent Systems: De Priester		Multicomponent Systems: Other Data		All Systems	
	Abs. % Dev.	No. of Points	Abs. % Dev.	No. of Points	Abs. % Dev.	No. of Points	Abs. % Dev.	No. of Points
Methane	5.4	36	5.9	26	7.4	24	6.1	86
Ethylene	4.6	10			4.0	4	4.4	14
Ethane	5.2	29	9.8	29	5.8	12	6.4	70
Propylene	1.9	9					1.9	9
Propane	4.2	21	7.0	28	6.7	16	6.3	65
1-Butylene	4.5	6			7.2	4	5.6	10
i-Butane	1.6	6	9.8	6			5.7	12
n-Butane	5.1	12	7.1	19	10.5	6	7.0	37
n-Pentane	4.5	11	16.7	7	8.8	12	9.1	30
n-Hexane					12.1	1	12.1	1
n-Heptane	9.1	8					9.1	8
2,2,4-Trimethylpentane			9.6	1			9.6	1
n-Decane			5.1	1	11.2	2	9.2	3
Average All Hydrocarbon This Correl.	4.4	148	8.2	117	7.4	81	6.4	346
De Priester Charts	6.3	88	6.3	116	6.7	54	6.4	258
Kellogg Chts	6.2	87	8.8	116	7.7	54	7.7	257

Evaluation of Correlation with *K*-Values

As indicated in Table 2, the agreement between the original Polyco fugacity charts and the proposed generalized activity coefficient correlation is good. However, a more practical test of the correlation is the prediction of vapor-liquid equilibrium distribution ratio. Accordingly, a comparison was made with experimental vapor - liquid K - values from the literature. The sources and ranges of data used are shown in Table 3, and results of the evaluation are presented in Table 4.

The literature data used in this evaluation are divided into three categories: (1) binary, (2) De Priester multicomponent, and (3) other multicomponent systems. Comparisons were made in this way because binary data are the most reliable (as a result of greater experimental accuracy) and because there is a large number of points in the De Priester multicomponent data. More points were used from this source than from any other single reference in order to put the proposed correlation to a severe test and to compare it with De Priester's recent recorrelation of the Kellogg charts. Many recent binary and multicomponent data not included in De Priester's evaluation have been used in the current work. Some of these additional data are for higher pressures or lower temperatures than the range covered by De Priester's charts.

Table 4 shows that the average absolute deviations of the proposed generalized activity coefficient correlation for all hydrocarbons are: 4.4% for 148 binary data points, 8.2% for the 117 De Priester multicomponent data points, and 7.4% for 81 other multicomponent data points. The average for all hydrocarbons in all systems is 6.4% for 346 data points.

Average deviations of De Priester and Kellogg charts for all hydrocarbons are included for comparison. The latter are from the evaluations made by De Priester and apply only to the pressure range of atmospheric to 1000 lb./sq.in. All the data points used by De Priester in his evaluations, plus the additional high pressure data, have been included in the evaluations of the proposed generalized correlation.

Sample Calculations

The application of this correlation will be illustrated by calculation of the K-values for a three-component mixture from the literature (*9*). Following are the experimental data and the calculated molal average boiling points for each equilibrium phase at 160° F. and 500 lb./sq.in. abs. pressure. The molal average boiling points are: $B = 288.1°\ R.$ and $B^L = 478.9°\ R.$ (see Table A, 1.)

Reduced conditions are next found from

$$B_r^V = B^V/B$$

$$B_r^L = B^L/B$$

$$T_r = (160 + 460)/T_c$$

$$P_r = 500/P_c$$

(See Table A-2).

With these reduced conditions, values of θ and the activity coefficients are found from the charts (Table A-3).

Values of P° at 160° F. are found from Table 1, and K-values are computed by Equation (*2*). These values are compared with the observed values in Table A-4.

In this example the compositions of the equilibrium phases were known and so the calculations were straightforward. Had these been unknown, successive approximations would have been necessary. These would start with assumed values of B^V and B^L, which would be found after the K-values had been calculated and the equilibrium phases computed.

thermodynamics

Table A.

A-1

Hydrocarbon	Observed Data: y	x	$K = y/x$	Atm. B.P., °R.	M.A.B.P. Calculations: yB	xB
Methane	0.661	0.116	5.70	201	132.9	23.3
Propane	0.238	0.259	0.919	416	99.0	107.7
n-Pentane	0.101	0.625	0.162	556.6	56.2	347.9
	1.000	1.00			288.1	478.9

A-2

Hydrocarbon	B	Ratio Boiling Point: B_r^V	B_r^L	Temperature: T_c	T_r	Pressure: P_c	P_r
Methane	201.0	1.435	2.38	343.2	1.806	673.0	0.743
Propane	416.0	0.692	1.15	666.0	0.931	617.4	0.810
n-Pentane	556.6	0.518	0.86	845.6	0.733	490.0	1.020

A-3

Hydrocarbon	Vapor Phase: θ^V	f'^V/Py	Liquid Phase: θ^L	$f'^L/P^\circ x$
Methane	2.47	1.009	1.215	0.385
Propane	0.99	0.715	0.900	0.79
n-Pentane	0.89	0.540	0.707	1.04

A-4

Hydrocarbon	$\frac{(f'^L/P^\circ x)}{(f'^V/Py)}$	P°	P°/P	K-Values: Calc.	Obs.
Methane	0.3815	7,523	15.05	5.74	5.70
Propane	1.105	389.3	0.778	0.860	0.919
n-Pentane	1.925	41.9	0.0838	0.161	0.162

Partial Enthalpy and Volume

Partial enthalpy and partial volume values can be derived from these generalized activity coefficient correlations by obtaining temperature and pressure derivatives.

The basic thermodynamic equations for these derivatives are

$$\Delta H' = H' - H^\circ$$

$$= -RT^2\left(\frac{\partial \ln f'/x}{\partial T}\right)_{P,N} \quad (3)$$

$$V' = RT\left(\frac{\partial \ln f'/x}{\partial P}\right)_{T,N} \quad (4)$$

These equations, which are general and applicable to either liquid or vapor phase, are transformed to separate equations in generalized units for each phase.

For the vapor phase the generalized partial enthalpy difference equation is:

$$\frac{\Delta H'^V}{RT_c} = -T_r^2\left(\frac{\partial \ln f'^V/Py}{\partial T_r}\right)_{P_r,B_r}$$

$$= -T_r^2\left[\left(\frac{\partial \ln f'^V/Py}{\partial \theta}\right)_{P_r}\left(\frac{\partial \theta}{\partial T_r}\right)_{B_r}\right] \quad (5)$$

The corresponding equation for the liquid phase must include a vapor pressure slope term.

$$\frac{\Delta H'^L}{RT_c} = -T_r^2\left(\frac{\partial \ln f'^L/x}{\partial T_r}\right)_{P_r,B_r}$$

$$= -T_r^2\left[\left(\frac{\partial \ln f'^L/P^\circ x}{\partial \theta}\right)_{P_r}\left(\frac{\partial \theta}{\partial T_r}\right)_{B_r}\right]$$

$$+\frac{d \ln P^\circ}{d\left(\frac{1}{T_r}\right)} \quad (6)$$

Above the atmospheric boiling point, where P° values were obtained from a straight line on log P° vs. $1/T$ plot, the last term in Equation (7) becomes

$$\frac{d \ln P^\circ}{d\left(\frac{1}{T_r}\right)} = \frac{\ln P_c/P_B}{1-\frac{T_c}{T_B}} \quad (7)$$

A generalized equation for the partial volume differences of the vapor phase may be obtained from Equation (4) by combining with the ideal gas volume ($V^\circ = RT/P$) and changing to reduced units:

$$\Delta V'\left(\frac{P_c}{RT_c}\right) = T_r\left(\frac{\partial \ln f'^V/Py}{\partial P_r}\right)_{T_r,B_r} \quad (8)$$

where

$\Delta V' = V' - V'^\circ$ = partial volume difference in the same units as RT_c/P_c.

Because of the vapor pressure term P°, the generalized equation for the partial enthalpy difference of the liquid contains an extra term. As the pressure derivative of vapor pressure is zero, Equation (4) is transformed to generalized dimensions for the liquid phase:

$$\Delta V'\left(\frac{P_c}{RT_c}\right) = T_r\left(\frac{\partial \ln f'^L/P^\circ x}{\partial P_r}\right)_{T_r,B_r}$$

$$-\frac{T_r}{P_r} \quad (9)$$

The pressure derivatives of the activity coefficients in Equations (9) and (10) are at constant T_r and B_r or at constant θ.

Conclusions

Generalized correlations, giving vapor and liquid activity coefficients as functions of reduced temperature, reduced pressure, and boiling point ratio, have been developed from the fugacity values recently obtained by Benedict et al. (1, 2) for twelve light hydrocarbons at pressures up to 3600 lb./sq.in. and are presented on 276 charts.

In the reduction of the data from 276 charts to six charts, a correlation was developed that can be used to estimate values for other hydrocarbons and conditions.

This correlation can be used directly in reduced units to obtain equilibrium vapor-liquid distribution ratios, or it can be used to prepare K-value plots for individual hydrocarbons with specific (° F. or ° C. and lb./sq.in. or atm. scales.

This correlation is applicable to paraffin and olefin hydrocarbon systems, as the data used in developing the correlation were for these hydrocarbons. The use of boiling points as the composition parameter may be considered as taking into account the effects of molecule size. For mixtures containing other hydrocarbons, such as aromatics or naphthenes, an additional composition correction for differences in molecule character must be applied.

Another application of these generalized activity correlations is the derivation of partial thermodynamic properties, such as partial enthalpy and volume.

Acknowledgment

The authors are indebted to G. G. Bejarano and the Richmond IBM Computation Laboratory of California Research Corporation for converting the raw data to generalized units and interpolating to even values of T_r and B_r for correlation purposes. The assistance of H. D. Eddy in evaluating the correlation is gratefully acknowledged.

Notation

R = universal gas constant, B.t.u./lb. mole ° R.

T = temperature, ° R.

$T_r = T/T_c$ = reduced temperature, where T_c is critical temperature, for any component

P = pressure, lb./sq.in.abs.

P° = vapor pressure, lb./sq.in.abs.

$P_r = P/P_c$ = reduced pressure where P_c is critical pressure for any component

B = normal atmospheric boiling point, ° R., for any component

B^V = molal average boiling point (ΣyB) of components in vapor phase, ° R.

$B_r^V = B^V/B$ = boiling point ratio for any component in the vapor phase

$B_r^L = B^L/B$ = boiling point ratio for any component in the liquid phase

θ^V = temperature-composition parameter for any component in vapor phase

θ^L = temperature-composition parameter for any component in liquid phase

f'^L/x = fugacity coefficient of any component

$f'^L/P^\circ x$ = activity coefficient of any component in liquid phase

f'^V/Py = activity coefficient of any component in vapor phase

$\Delta H' = H' - H^\circ$ = partial enthalpy difference for any component

$\Delta V' = V' - RT_c/P_c$ = partial volume difference for any component

Literature Cited

1. Benedict, M., E. Solomon, and L. C. Rubin, *Ind. Eng. Chem.*, **37**, 55 (1945).
2. Benedict, M., G. B. Webb, L. C. Rubin, and L. Friend, *Chem. Eng. Progr.*, **47**, 419-422; 449-454; 571-578, and 609-620 (1951).
3. Billman, G. W., B. H. Sage, and W. N. Lacey, *Am. Inst. Mining Met. Engrs., Tech. Pub.* 2232 (1947).
4. Bloomer, O. T., D. C. Gami, E. C. Kovacik, and J. D. Parent, Paper presented at A.I.Ch.E. San Francisco meeting (September, 1953).
5. Canjar, L. N., and W. C. Edmister, *Chem. Eng. Progr. Symposium Series*, No. 7, **49**, 73, 85 (1953).
6. Carter, R. T., B. H. Sage, and W. N. Lacey, *Am. Inst. Mining Met. Engrs. Tech. Pub.*, 1250 (1940)
7. Cummings, L. W. T., F. W. Stones, and M. A. Volante, *Ind. Eng. Chem.*, **25**, 728 (1933).
8. De Priester, C. L., *Chem. Eng. Progr., Symposium Series No. 7*, **49**, 1 (1953).
9. Dourson, R. H., B. H. Sage, and W. N. Lacey, *Am. Inst. Mining Met. Engrs. Tech. Publ.* 1490 (1942).
10. Edmister, W. C., *Ind. Eng. Chem.*, **30**, 352 (1938).
11. Edmister, W. C., *Petroleum Refiner*, **28**, No. 2, 137 (Feb., 1949).
12. Gamson, B. W., and K. M. Watson, *Nat. Petroleum News*, **36**, R-623 (1944).
13. Hadden, S. T., *Chem. Eng. Progr.*, **44**, 37-54 and 135-156 (1948).

14. Hadden, S. T., *Chem. Eng. Progr. Symposium Series* No. 7, **49**, 53 (1953).
15. Hanson, G. H., and G. G. Brown, *Ind. Eng. Chem.*, **44**, 604 (1952).
16. Hanson, G. H., R. J. Hogan, W. T. Nelson, and M. R. Cines, *Ind. Eng. Chem.*, **44**, 604 (1952)
17. Hanson, G. H., R. J. Hogan. F. N. Ruehlen, M. R. Cines, *Chem. Eng. Progr. Symposium Series*, No 6, **49**, 37 (1953).
18. Joffe, J., *Ind. Eng. Chem.*, **40**, 1738 (1948).
19. Katz, D. L., and G. G. Brown, *Ind. Eng. Chem.*, **25**, 1373 (1933).
20. Kay, W. B., *Ind. Eng. Chem.*, **28**, 1014 (1936).
21. Kay, W. B., *Ind. Eng. Chem.*, **32**, 353 (1940).
22. The M. W. Kelogg Company, Sixth Progress Report, Polymerization Process Corporation, Research Project E, Appendix A (February, 1942).
23. The M. W. Kellogg Company, "Liquid-Vapor Equilibria in Mixtures of Light Hydrocarbons MWK Equilibrium Constants, Polyco Data" (1950).
24. Lewis, G. N., and M. Randall, "Thermodynamics," McGraw-Hill Book Co., New York (1923).
25. Lewis, W. K., and W. C. Kay, *Oil Gas J.*, p. 40 (March 29, 1934).
26. Newton, R. H., *Ind. Eng. Chem.*, **27**, 302 (1935).
27. Olds, R. H., B. W. Sage, and W. N. Lacey, *Ind. Eng. Chem.*, **34**, 1008 (1942).
28. Organick, E. I., and G. G. Brown, *Chem. Eng. Progr., Symposium Series* No. 2, **48**, 97 (1952).
29. Organick, E. I., *Chem. Eng. Progr. Symposium Series* No. 6, **49**, 81 (1953).
30. Papadopoulos, P., R. L. Pigford, and L. Friend, *Chem. Eng. Progr. Symposium Series*, No. 7, **49**, 119 (1953).
31. Reamer, H. H., J. M. Fishkin, and B. H. Sage, *Ind. Eng. Chem.*, **41**, 2871 (1949).
32. Reamer, H. H., B. H. Sage, and W. N. Lacey, *Ind. Eng. Chem.*, **42**, 534 (1950).
33. Reamer, H. H., B. H. Sage, and W. N. Lacey, *Ind. Eng. Chem.*, **43**, 1436 (1951).
34. Roland, C. H., D. E. Smith, and H. H. Kaveler, *Oil Gas J.*, **39** (46), 128 (1941).
35. Rossini, F. D., et al., A.P.I. Research Project 44, Carnegie Inst. Tech., Pittsburgh.
36. Rzasa, M. J., E. D. Glass, and J. B. Opfell, *Chem. Eng. Progr. Symposium Series* No. 2, **48**, 28 (1952).
37. Sage, B. H., B. L. Hicks, and W. N. Lacey, *Ind. Eng. Chem.*, **32**, 1085 (1940).
38. Scheeline, H. W., and E. R. Gilliland, *Ind. Eng. Chem.*, **31**, 1050 (1939).
39. Smith, K. A., and K. M. Watson, *Chem. Eng. Progr.*, **45**, 494 (1949).
40. Souders, M., C. W. Selheimer, and G. G. Brown, *Ind. Eng. Chem.*, **24**, 517 (1932).
41. Taylor, H. S., G. W. Wald, B. H. Sage, and W. N. Lacey, *Oil Gas J.*, **38**, No. 10, 46 (1939).
42. Winn, F. W, *Chem. Eng. Progr. Symposium Series* No. 2, **48**, 121 (1952).

Presented at A.I.Ch.E. meeting, Washington, D. C.

SMOG

W. L. Faith | Air Pollution Foundation

The air pollution problem of any community is a function of the amount and type of pollutants emitted to the atmosphere, and of the rate and mechanism of the removal of these pollutants from the atmosphere. Wherever or whenever extremely large amounts of pollutants enter the air, or when the air volume is restricted or stagnant, a high frequency of air pollution attacks may be expected. Restricted air volumes in the open atmosphere usually result from the combination of an atmospheric temperature inversion and low wind velocities. Meteorologically, an inversion is an atmospheric condition in which the air temperature increases as one goes upward, instead of decreasing. Inversions may occur beginning at the surface of the ground, or at some higher level. When an inversion exists, air will circulate freely only between the ground surface and the base of the inversion, the point at which the air temperature begins to increase with increasing height. The base of the inversion has been likened to a lid, confining all gases and vapors below it to lateral movement.

W. L. (Larry) Faith is, in addition to being a director of A.I.Ch.E., deputy director and chief engineer for the Air Pollution Foundation, Los Angeles, Calif.

Battery of chambers for studying effect of artificial smog on plants—University of California at Riverside, California.

U. S. Navy blimp taking air samples near Los Angeles City Hall on a smoggy day.

The commonest type of inversion in the Eastern and Midwestern areas of the United States is the so-called "radiation" inversion, brought about by rapid cooling of the earth's surface during the night when the air is essentially stagnant. Persistent fogs in river valleys, in the Great Lakes region, and in coastal areas are a sort of natural air pollution where the contaminants consist of finely divided droplets of water which are condensed from the air by the cooling which produces the radiation inversion.

When smoke, soot, and various gaseous emissions are present along with fog, we have the black smog for which London is notorious and which, at one time, was typical of Pittsburgh and St. Louis. Pittsburghers now brag of their "clean" fogs. Obviously, they still have inversions, but emissions of smoke and soot have been reduced.

The other type of inversion is the "subsidence" inversion experienced on the West Coast of the United States. This widespread inversion is a function of the semipermanent Pacific High extending over the eastern Pacific Ocean off the West Coast of the United States. As a consequence, an inversion is present over Southern California approximately 260 days per year. At times it touches the surface; at other times, its base may be several thousand feet above the ground. In consideration of this frequent inversion, the local topography, and generally low average wind velocities, the capacity of the Los Angeles atmosphere for gas-borne pollutants would normally be expected to be low. And, to be sure, as Los Angeles grew and emissions of pollutants increased, smog appeared more and more frequently, beginning in the early 1940's. The community went to work through its Air Pollution Control District and markedly reduced emissions of smoke and sulfur dioxide. These methods had worked effectively in other cities, but in Los Angeles the smog grew worse. A new phenomenon was noticed. In practically all communities elsewhere, smog accompanied fog. But here, some of the worst smog attacks occurred on days of relatively low humidity. Furthermore, in addition to low visibility, heavy smog created widespread eye irritation and, to many, was accompanied by a very noticeable objectionable odor, best described only as "typical." Many times after a smog attack, a new type of damage to leafy vegetable crops, called "bronzing" or "silvering," appeared. In addition, chemical analysis of the atmosphere showed a much higher than normal "ozone" (at least an ozone-like material) content. In most urban communities, the ozone content of the atmosphere is in the neighborhood of five parts per hundred million (5 pphm). During heavy smog attacks in Los Angeles, this value has reportedly reached 80 pphm.

So Los Angeles smog has several different, sometimes concurrent, manifestations. These are generally considered to be low visibility, eye irritation, "typical" odor, plant damage, and a high atmospheric ozone or "oxidant" content.

Several years ago the formation of Los Angeles smog was explained by Haagen-Smit as the result of the photosensitized reaction of hydrocarbons and nitrogen dioxide to form ozone as one of the intermediate reaction products. This theory, backed up by experiment,

Typical back-yard incinerator in Los Angeles.

explained the high atmospheric ozone concentration which reaches a peak several hours after sunrise, and always decreases to practically zero after sundown. It was also reported that synthetic smog, made by reaction of olefinic hydrocarbons and ozone, showed the characteristics of natural smog, i.e., reduced visibility, eye irritation, typical odor, and plant damage.

As a consequence of this work and other evidence, comparatively drastic regulations were enacted, forcing petroleum refineries in the area to greatly reduce their emissions of hydrocarbons to the atmosphere—an operation which supposedly has cost the petroleum industry about twenty million dollars. Whether or not the frequency of smog attacks will be reduced remains to be seen, as installations are just being completed. Currently, however, no one expects a noticeable reduction.

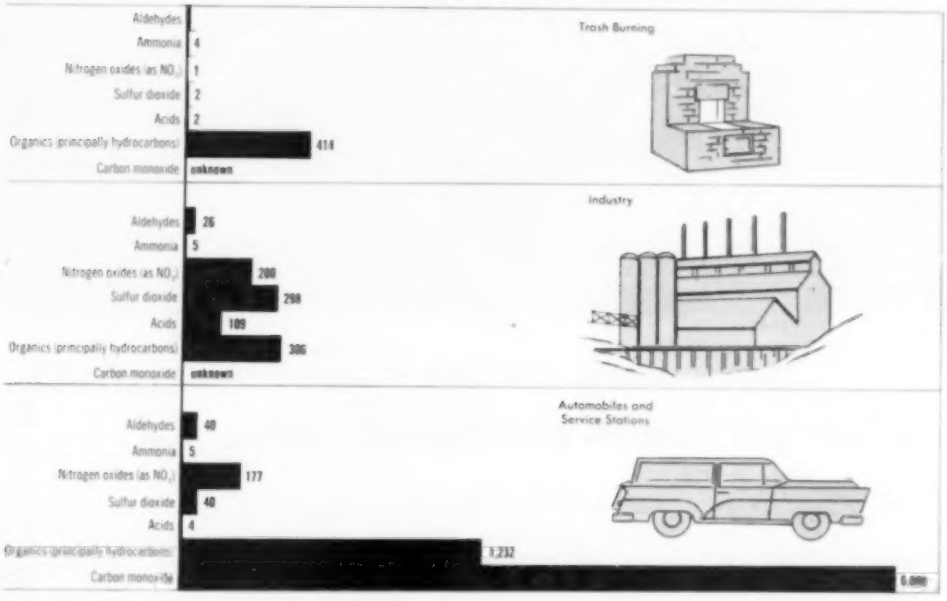
What, then, is the remedy for Los Angeles smog? To evaluate the situation, we must return to the fundamental causes of any air pollution problem, specific meteorological conditions and the amount and character of emissions. In all probability there is little hope that the meteorology of the Los Angeles Basin can be changed. So the obvious remedy is reduction of emissions, particularly those responsible for the obnoxious characteristics of smog.

But we still don't know which emissions are responsible. Is it a matter of quantity or type? Does one material activate the action of another? Do materials harmless in themselves become extraordinarily active in the presence of other materials in low concentration, or are their activities only additive? Unfortunately, few answers are available.

An inventory of the principal emissions to the atmosphere, aside from smoke, shows three main sources: the automobile, back-yard burning of refuse, and various industrial emissions. An approximate breakdown of the daily tonnage of various types of pollutants from these sources is shown in the accompanying table.

Daily Gaseous Emissions from Selected Sources

Los Angeles County—1953 *(Tons per Day)*



NOTE: This table is based on Tables XLIV and XLVI, "The Smog Problem in Los Angeles County," Stanford Research Institute (1954).

It will be noticed from the table that, if the hydrocarbon theory of smog formation is correct, the hydrocarbon content of auto exhaust must be curtailed and, in fact, is a much more important item than the hydrocarbon emissions from refineries. Accordingly, further clarification of the role of hydrocarbons in smog formation is necessary. The main point at issue is disagreement between capable investigators that hydrocarbon oxidation reactions are responsible for actual smog manifestations. It is quite possible, of course, that other gaseous emissions may be equally or even more obnoxious than hydrocarbons. A great deal more research in atmospheric chemistry and physics, instrument development, and statistical correlations remains to be done to delineate more clearly the function of many gaseous emissions.

It is obvious that visible emissions such as smoke from back-yard burners, diesel trucks and buses, and industrial stacks must be controlled to a level commensurate with the volume of the air mass of the locality. The control of nonvisible emissions is another matter. Different control and inspection methods will have to be developed for each chemical entity. Before embarking on this type of program, further identification of the major smog contributors is essential. On the other hand, one cannot escape the fact that currently the two and one-half million automobiles in the Los Angeles Basin contribute, through their exhaust, the greatest tonnage of pollutants to the atmosphere. Control of these emissions alone presents a real challenge to the engineering profession.

lead reference sheet (part 2)

Kempton H. Roll Technical Director, Lead Industries Association, New York

Corrosion Characteristics of Lead:

Lead relies for its resistance to corrosion upon a thin protective coating which forms on its surface. When the coating is one of the highly insoluble lead salts such as sulphate, carbonate or phosphate, resistance to corrosion is high and the environment generally promotes self-healing of the coating upon mechanical injury. On the other hand, if soluble films form such as the nitrate, acetate, or chloride, little protection is afforded and the lead may corrode further. Likewise, if insoluble protective coatings are removed mechanically, as by abrasion, or erosion, or dissolved chemically as in the case of some mixed corrosives, corrosion resistance is similarly reduced.

The manner of installation, proper design, and awareness of the exact service conditions are all important in lead chemical construction in order to minimize the mechanical limitations of lead and to take advantage in the best way of its superior corrosion characteristics.

CORROSION RESISTANCE*

ACIDS:

Acetic, dilute	N
Acetic, glacial	F
Arsenic	G
Boric	E
Carbonic	F
Chromic	E
Fatty	G
Formic, concentrated	F
Hydrochloric, up to 20%	G
Hydrochloric, above 20%	P
Hydrocyanic	G
Hydrofluoric	F
Mixed acids	G
Nitric, dilute	N
Nitric, conc.	G
Oxalic-sulfuric	E
Phosphoric	E
Salicylic	E
Sulfuric, below 96%	E
Sulfuric, above 96%	P
Sulfurous	E
Tannic, Conc.	F
Tartaric	E

ALKALIES:

Ammonium hydroxide	F
Calcium hydroxide	F
Potassium hydroxide, up to 30%	G
Sodium hydroxide, up to 30%	G

ACID SALTS:

Alum or Aluminum sulfate	E
Ammonium chloride, up to 10%	F
Ammonium fluoride	F
Ammonium phosphate	G
Bisulphates	E
Calcium acid phosphate	E
Chromates	E
Ferric chloride	N
Ferrous chloride	G
Nitrates	F
Phosphates	E
Sulfates	E

ALKALINE SALTS:

Barium sulfide	E
Calcium bisulfite	E
Calcium carbonate	E
Phosphorus oxychloride	E
Potassium metabisulfite	E
Sodium bisulfite	E
Sodium carbonate, dilute sol'ns	E
Sodium chlorite, dilute	F
Sodium hypochlorite	N
Sodium hyposulfite	F
Sodium sulfide	G
Sodium sulfite, up to 20%	F
Zinc hydrosulfite	E

NEUTRAL SALTS:

Calcium chloride	G
Magnesium chloride	P
Magnesium sulfate	E
Sodium chloride	E

GASES:

Acetylene	E
Ammonia, dry	E
Ammonia, wet	G
Bromine, cold	F
Carbon dioxide	E
Chlorine, dry	E
Chlorine, wet	G
Hydrogen chloride, dry	G
Oxygen, dry	E
Oxygen, wet	F
Sulfur dioxide	E
Sulfur trioxide	E

ORGANIC MATERIALS:

Acetone	E
Acetophenone	E
Alcohol	E
Benzol, pure	E
Benzyl chloride	E
Benzyl phenol	E
Carbon tetrachloride	G
Chlorobromomethane, dry	G
Ether	E
Hexachlorbutadiene	E
Hexachlorethane	E
Naphthalene	G
Nitro-benzol	N
Nitroglycerin	G
Pentachlorethane	G
Phenol	E
Pyridine	E
Urea	E

OTHERS:

Antimony chloride	F
Hydrogen peroxide	F
Mercuric sulfate	F
Potassium permanganate	N

PAPER MILL APPLICATIONS:

Alum	E
Chlorine bleach	G
Chlorite bleach	N
Sulfur dioxide	E
Sulfite liquor	E

PHOTOGRAPHIC INDUSTRY:

General use	G

FERTILIZER INDUSTRY:

General use	E
Superphosphate	E

STEEL INDUSTRY:

Hydrochloric acid pickling	P
H_2SO_4—HNO_3 acid pickling	F
Sulfuric acid pickling	E

TEXTILE INDUSTRY:

Rayon solutions	E

PLATING INDUSTRY:

Anodizing	E
Chromium	E
Copper	E
Hard chrome	E
Nickel	E
Waste disposal	E

* Data applies to A.S.T.M. Chemical Grade Lead.

E—Excellent resistance. Corrosion so slight as to be harmless.

G—Good resistance. Satisfactory service expected.

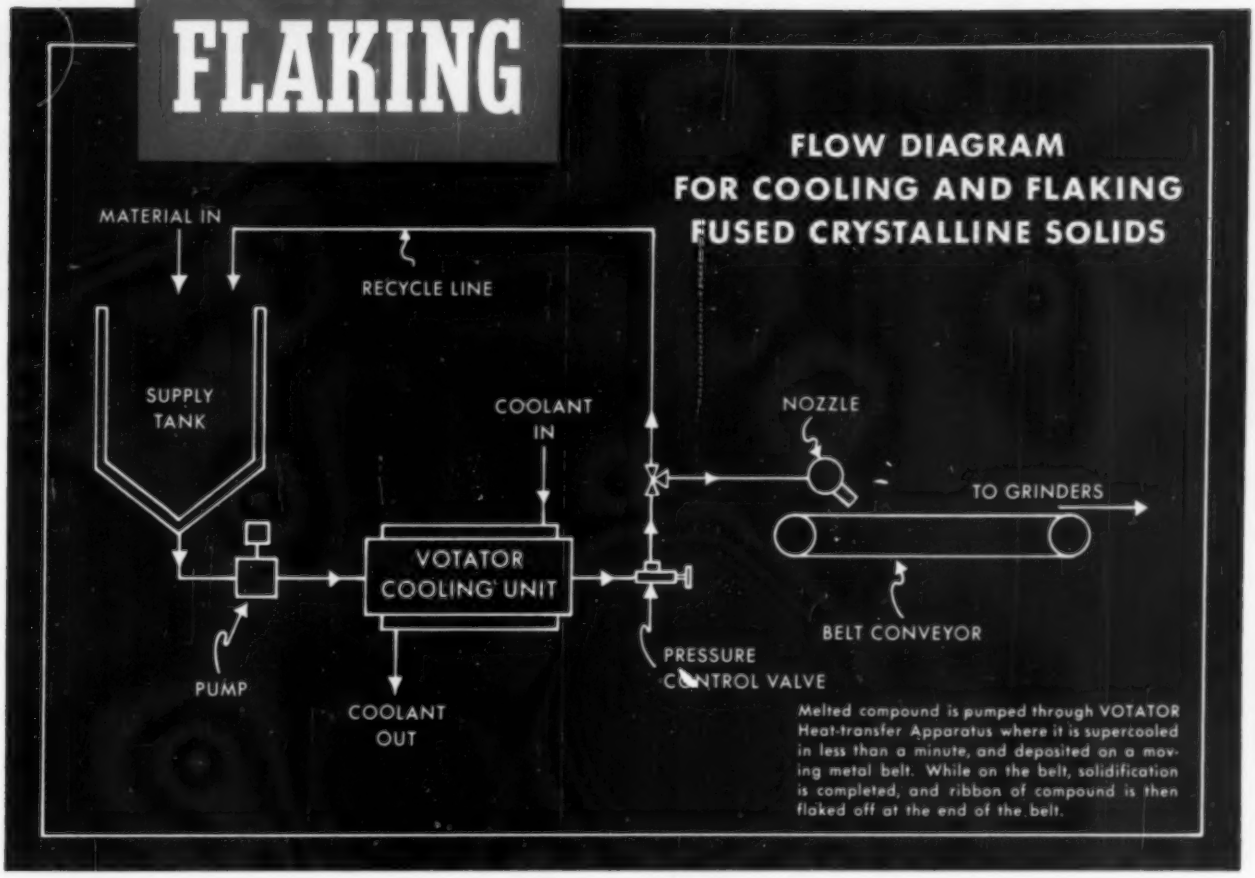
F—Fair resistance. Satisfactory service under specific conditions.

P—Poor resistance. Satisfactory for temporary service only.

N—No resistance. Rate of attack too great for any use.

No. 42

FLAKING


FLOW DIAGRAM
FOR COOLING AND FLAKING
FUSED CRYSTALLINE SOLIDS
MATERIAL IN
RECYCLE LINE
SUPPLY TANK
COOLANT IN
NOZZLE
TO GRINDERS
VOTATOR COOLING UNIT
BELT CONVEYOR
PRESSURE CONTROL VALVE
PUMP
COOLANT OUT
Melted compound is pumped through VOTATOR Heat-transfer Apparatus where it is supercooled in less than a minute, and deposited on a moving metal belt. While on the belt, solidification is completed, and ribbon of compound is then flaked off at the end of the belt.

Controlled supercooling with Votator® Heat-transfer Apparatus produces better crystal structure

A NEW PROCESS for flaking fused crystalline solids employs VOTATOR* Heat-transfer Apparatus for continuous supercooling under precise mechanical control. Applications include DDT and similar compounds (methoxychlor), which on cooling from the melted state supercool to a marked degree. The VOTATOR Heat-transfer Apparatus supercools them to a slush or semi-solid.

This automatic continuous process permits very accurate control of crystallization temperature and other solidifying conditions. As a result, the flaking material has a uniformly fine crystal structure with excellent grinding properties. Without such continuous, positive control, crystallization can be retarded, or the flakes can become waxy and difficult to grind properly. The system is completely enclosed, eliminating danger to personnel from toxic compounds. Automatic operation reduces labor requirements and permits efficient operation at various production rates.

VOTATOR Heat-transfer Apparatus can improve efficiency and product quality in many processes such as listed. Write for copy of Heat Transfer Data Book.

*VOTATOR Trade-Mark Reg. U.S. Pat. Off.

GIRDLER DESIGNS processes and plants
GIRDLER BUILDS processing plants
GIRDLER MANUFACTURES processing apparatus

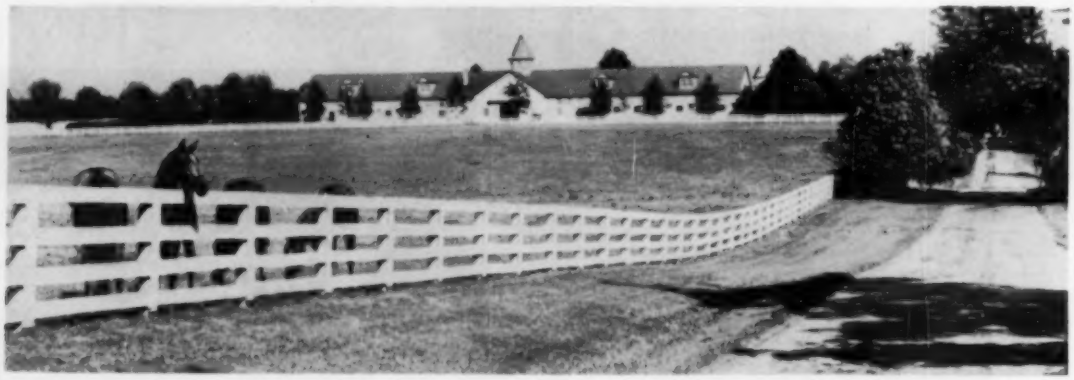
VOTATOR DIVISION:
Complete Edible Oil Plants;
Continuous Processing Apparatus for . . .

Cooking	Sulfation	Lubrication Grease
Cooling	Nitration	Paper Coating
Controlling Heat of Reaction	Crystallization	Paraffin Wax
	Polymerization	Synthetic Wax
Emulsification	Textile Size	Resins
Sulfonation	Shaving Cream	And other Products

The GIRDLER Company

A DIVISION OF NATIONAL CYLINDER GAS COMPANY
LOUISVILLE 1, KENTUCKY

VOTATOR DIVISION: New York, Atlanta, Chicago, San Francisco
GAS PROCESSES DIVISION: New York, Tulsa, San Francisco
In Canada: Girdler Corporation of Canada Limited, Toronto



BLUEGRASS Country

by G. J. Schaaf
DuPont, Louisville, Ky.

Springtime in Kentucky is when long-legged foals scamper with the abandon of youth, behind spick-and-span white fences of bluegrass estates. As one approaches the historic city of Louisville to attend the spring national meeting of the A.I.Ch.E., he will sense the contrast, and yet the harmony between the spaciousness of the sports-loving countryside, and the modern chemical processing industries showing their presence in increasing numbers.

Louisville, experienced host to thousands at its annual Kentucky Derby, will offer its charm to the hundreds of members and guests of the Institute during the meeting to take place at the Kentucky Hotel, March 20-23, 1955.

Historic lore

De LaSalle first sighted the territory that is now Louisville in 1670 but it was a century later when George Rogers Clark founded the first settlement. By 1820, the population was 4,000 and there was a thriving business center at the waterfront. By that time, Louisville had two saw mills, five tobacco factories, two breweries, two distilleries, six brickyards, three chair factories, a brass foundry, a sugar refinery and a nail factory. In 1840, Louisville became the first city in the west to use gas lights. During the Civil War, Louisville became known as "The Gateway City" because of large troop movements by rail. By 1870, the population had reached 100,000. Louisville played an important role in World War I with its Camp Zachary Taylor and continued that role to the present with nearby (thirty miles south) and world famous Fort Knox.

During World War II, Louisville was introduced to the chemical industry with the location of "Rubbertown." Here, du Pont, B. F. Goodrich, Union Carbide & Carbon, and the National Synthetic Rubber Corp. built and operated plants manufacturing various elastomers. Chemical Engineers associated with these new industries and the old distillery industry organized a local section in the spring of 1944. Since that time, the section has held monthly meetings, sponsoring many well-known speakers and arranging many plant trips. The present officers of the section are: W. M. Glenn, President (du Pont), F. J. Sackfield, Vice Chairman (Ky. Synthetic), and A. W. Clements, Secretary-Treasurer (B. F. Goodrich).

What to see and do

A comprehensive technical program, plant visits to diverse local industries, and world famous local sights should offer a most promising time for all. The industrial growth of Louisville since the previous sessions there in 1947 will be seen in visits to the new facilities of Olin Mathieson, to General Electric's vast new "Appliance Park," and to several old favorites such as Seagram's Distillery and du Pont's Neoprene Plant. The technical program includes a joint symposium on heat transfer with the ASME. Symposia on propellant power, solvent extraction and centrifugation should be popular.

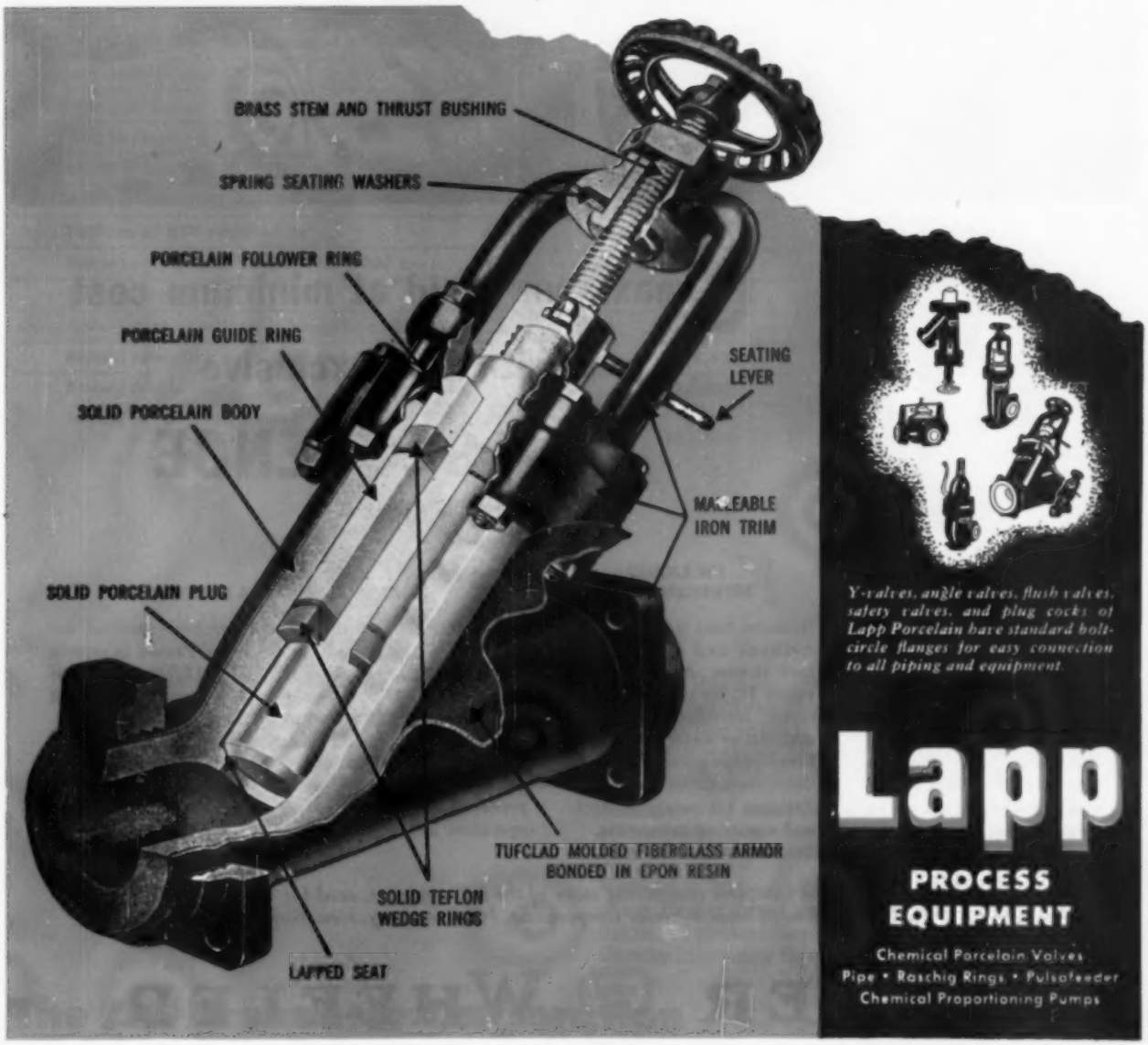
The visitor can see renowned Churchill Downs which lies a short distance from the business district. He can have this opportunity without the temptations of the two-dollar window. But it will be possible to drive by horses at typical breeding farms without leaving Jefferson County in which Louisville lies. For those wishing to go farther afield, well known horse farms such as Calumet can be seen at Lexington. While there, the visitor would probably

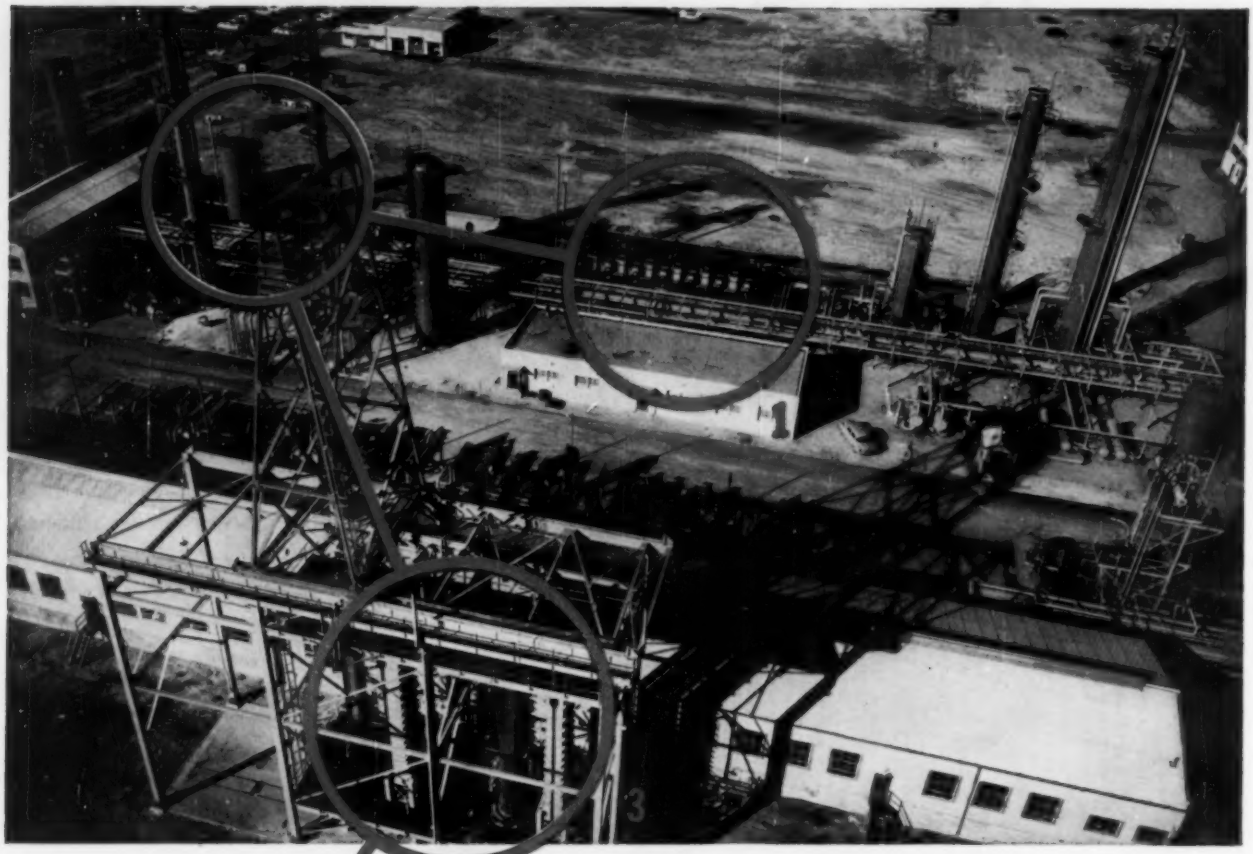
(*Continued on page* 34)

Precision Grinding of Solid Porcelain in the Lapp Valve

The high firing temperature, which assures complete vitrification and zero porosity of Lapp Porcelain, also makes impossible the maintaining of close dimensional tolerances. Necessary tolerances are achieved, however—in regular production ±.001″—by machine grinding with silicon carbide wheels. In the Lapp Valve, the entire stuffing box chamber, seating area, plug, guide and follower rings are finish ground, for precision assembly and complete interchangeability of parts. In addition, each porcelain plug is individually lapped and polished into its seat integral in the valve body. (No separable seating parts.) Each such valve seal is tested to 150 psi hydrostatic pressure before the valve is shipped.

Write for bulletin with complete description, characteristics, and specifications. Lapp Insulator Co., Inc., Process Equipment Division, 341 Wendell St., LeRoy, New York.


BRASS STEM AND THRUST BUSHING
SPRING SEATING WASHERS
PORCELAIN FOLLOWER RING
PORCELAIN GUIDE RING
SOLID PORCELAIN BODY
SOLID PORCELAIN PLUG
SEATING LEVER
MALLEABLE IRON TRIM
TUFCLAD MOLDED FIBERGLASS ARMOR BONDED IN EPON RESIN
SOLID TEFLON WEDGE RINGS
LAPPED SEAT
Y-valves, angle valves, flush valves, safety valves, and plug cocks of Lapp Porcelain have standard bolt-circle flanges for easy connection to all piping and equipment.
Lapp
PROCESS EQUIPMENT
Chemical Porcelain Valves
Pipe • Raschig Rings • Pulsafeeder
Chemical Proportioning Pumps



NH_3

maximum yield at minimum cost with this exclusive

FW SEQUENCE

1 TEXACO PARTIAL OXIDATION

Reforms natural gas to produce mixture of H_2 and CO. No catalyst required. Uses simple, refractory-lined vessel—no complex furnace with expensive alloy tubes. Not affected by sulphur content in feed stream. Easily convertible to fuel oil instead of gas.

2 FW LIQUID NITROGEN WASH

Removes final traces of CO, methane and argon from feed stream. Assures high-purity H_2 for ammonia synthesis. Introduces no inert material or water vapor and keeps purge gases from synthesis train to the minimum. Reduces laboratory control and operating manpower.

3 CASALE AMMONIA SYNTHESIS

The simplest, most dependable synthesis method for producing liquid anhydrous ammonia. Proved in service the world over. Operation at 9,000 to 12,000 psi assures high conversion per pass, results in small equipment and permits condensation to liquid ammonia with cooling water only. No refrigeration required. Uses simple ejector for recycling—no recirculating compressor, no danger of oil contamination. Extreme simplicity of process flow reduces the cost of equipment, installation, operation and maintenance.

For the complete cost-saving story of the FW sequence, send for Bulletin No. 0-54-1. Foster Wheeler Corporation, 165 Broadway, New York 6, N. Y.

FOSTER WHEELER

HERE'S HOW ONE REFINER SAVED WITH A LJUNGSTROM

COMPARATIVE FUEL AND POWER COSTS

	WITH AIR HEATER	WITHOUT AIR HEATER
Heat absorption /hr millions of BTU	100	100
Oil—inlet temp.—°F	700	700
Flue gas temp. to stack—°F	400	950
CO_2 to stack—%	10.0	11.0
O_2 to stack—%	5.2	3.7
EFF (assuming 5% radiation loss)—%	78.5	66.0
Millions of BTU required/hr	127.39	151.52
Annual cost of fuel ($2.50/Bbl—8000 hrs)	$392,000	$466,200
Kilowatt-hours	80	
Annual cost of energy @ 1¢/kwh—8000 hrs	$6,400	
Annual operating cost—fuel and energy—8000 hrs	$398,400	$466,200
Annual fuel savings	$74,200	
Annual net savings in operating costs (fuel savings less energy costs)	$67,800	

Wherever you burn fuel, you need LJUNGSTROM

Listed in this table are comparative fuel and power costs for operating two identical deFlorez stills, one with and one without a Ljungstrom® Air Preheater. Operating costs *without* the Ljungstrom reflect performance with a convection bank of tubes.

Remember: the initial cost of a Ljungstrom installation often is more than offset by the savings reflected in eliminating the convection bank.

Remember, too — operating savings are only part of the story. Higher flame temperatures developed through the use of preheat increases heat transfer to oil tubes — thereby increasing throughput.

The Air Preheater Corporation 60 East 42nd St., New York 17, N. Y.

Olin Mathieson plant at Brandenburg, Ky.

BLUEGRASS COUNTRY

(*Continued from page* 30)

wish to see the University of Kentucky. But a short ride from downtown is the University of Louisville, the oldest municipal university west of the Alleghenies. Not too far away is famous Fort Knox and picturesque Lexington.

Hotels, transportation, restaurants

The headquarters hotel, the Kentucky, has single rooms from $5.00 to $8.50 and doubles for $8.00 to $14.00. Suites are available, from $16.00 to $20.00. Other large, first-class hotels are the Brown, Henry Clay, Seelbach and Henry Watterson. All of these are within a very short walking distance of the Kentucky. Eating accommodations are available at all of these hotels. Literature will be distributed at the Registration Desk which will guide you to these or to other fine restaurants in both the downtown and outlying areas.

Louisville is served by four major airlines: American, Eastern, Piedmont, and TWA, which land at Standiford Field, approximately a ten-minute taxi ride from the shopping and hotel area.

Railroads coming into Louisville include the L&N, Pennsylvania, CI&L, B&O, Illinois Central and C&O. Greyhound bus service is also available.

Social calendar

Make certain to arrive in Louisville *Sunday afternoon*. Registration facilities will be in operation at the meeting headquarters on the mezzanine of the Kentucky Hotel until eight p.m.

The "get acquainted party" will be held *Sunday evening* at eight in the Terrace room of the Kentucky Hotel. *Monday* evening will be devoted to chemical engineering sportsmen who like to "play" the races . . . the affair will be a "derby" party, otherwise known as "a day at the races."

Tuesday will again be the traditionally heavy day for social events. At noon there will be a "buzz" luncheon, leading into a panel discussion on industrial relations.

(*Continued on page* 42)

TECHNICAL PROGRAM

Louisville meeting

Monday, March 21, 1955

TECHNICAL SESSION NO. 1

(Simultaneous with Session No. 2)

GENERAL PAPERS, R. M. Reed, Presiding.

NEW METHOD FOR OBTAINING VAPOR-LIQUID EQUILIBRIUM DATA, F. M. Tiller, Lamar State College of Technology, Beaumont, Texas; and R. S. Ramalho and M. D. Peterson, Vanderbilt University, Nashville, Tenn.

FORCES ACTING IN FLOWING BEDS OF SOLIDS, John W. Delaplaine, Cox and Weinrich, Washington, D. C.

DESIGN AND DEVELOPMENT OF SEALLESS PUMPS, D. P. Litzenberg and H. T. White, Chempump Corp., Philadelphia, Pa.

TECHNICAL SESSION NO. 2

(Simultaneous with Session No. 1)

A.I.Ch.E.—A.S.M.E. JOINT HEAT TRANSFER SYMPOSIUM, S. W. Churchill, Presiding.

THE CONCENTRATION OF GR-S LATEX IN A TURBULENT FILM EVAPORATOR, E. L. Borg, R. L. Provost, and C. V. Bawn, Naugatuck Chemical Division, U. S. Rubber Company, Naugatuck, Conn.

HEAT TRANSFER FOR VAPORIZATION OF WATER IN A VERTICAL TUBE, C. E. Dengler, and J. N. Addoms, M.I.T., Cambridge, Mass.

A STUDY OF HEAT TRANSFER TO ORGANIC LIQUIDS IN SINGLE TUBE NATURAL CIRCULATION VERTICAL TUBE BOILERS, S. A. Guerrieri and R. Talty, Univ. of Delaware, Newark, Del.

CIRCULATION RATES AND OVERALL TEMPERATURE DRIVING FORCES IN A VERTICAL THERMOSYPHON REBOILER, A. I. Johnson, du Pont Company of Canada, Ltd., Maitland, Ont.

PRESSURE DROP DURING FORCED-CIRCULATION BOILING, G. Leppert, Stanford Univ., Stanford, Calif., M. Jakob, Illinois Institute of Technology, Chicago, Ill., J. B. Reynolds, Dow Chemical Co., Midland, Mich.

EFFECT OF AIR RATE, WATER RATE, TEMPERATURE AND PACKING DENSITY ON A CROSS FLOW COOLING TOWER, N. W. Snyder, Univ. of California, Berkeley, Calif.

TECHNICAL SESSION NO. 3

(Simultaneous with Session No. 4)

SOLVENT EXTRACTION SYMPOSIUM, R. B. Beckmann, Presiding.

WATER EXTRACTION OF MILORGANITE FERTILIZER TO PRODUCE A VITAMIN B-12 CONCENTRATE, W. F. Stevens, B. Wolnak, and R. E. Zinn, Northwestern Technological Institute, Evanston, Illinois.

STUDIES IN THE RATE OF FALL OF LIQUID DROPLETS, Wm. Licht and G. S. R. Narasimhamurty, University of Cincinnati, Cincinnati 21, Ohio.

PREDICTION OF IDEAL STAGE REQUIREMENTS IN COMPLEX LIQUID-LIQUID EXTRACTION SYSTEMS, H. C. Peterson and G. H. Beyer, Iowa State College, Ames, Iowa.

OPERATING CHARACTERISTICS OF THE PUMP-MIX, MIXER SETTLER, J. H. Holmes and A.C. Schafer, Jr., Knolls Atomic Power Lab., General Electric Company, Schenectady, New York.

PHENOL EXTRACTION FROM INDUSTRIAL WASTES WITH THE ROTATING DISC CONTACTOR (R D C), David C. MacLean, Turbo-Mixer Division, J. R. Spraul, and J. Crowl, General American Transportation Corporation, New York, N. Y.

TECHNICAL SESSION NO. 4

(Simultaneous with Session No. 3)

A.I.Ch.E.—A.S.M.E. JOINT HEAT TRANFER SYMPOSIUM, A. C. Mueller, Presiding.

MEASUREMENT AND PREDICTION OF DENSITY TRANSIENTS IN A VOLUME HEATED BOILING SYSTEM, R. P. Lipkis, G. Liu, and N. Zuber, Univ. of California at Los Angeles, Los Angeles, Calif.

(*Continued on page* 38)

YOU CAN PUMP IN CONTROLLED VOLUME

HYDROCHLORIC ACID... ALL CONCENTRATIONS

CHLORINATED HYDROCARBONS

CORROSIVE METALLIC SALT SOLUTIONS

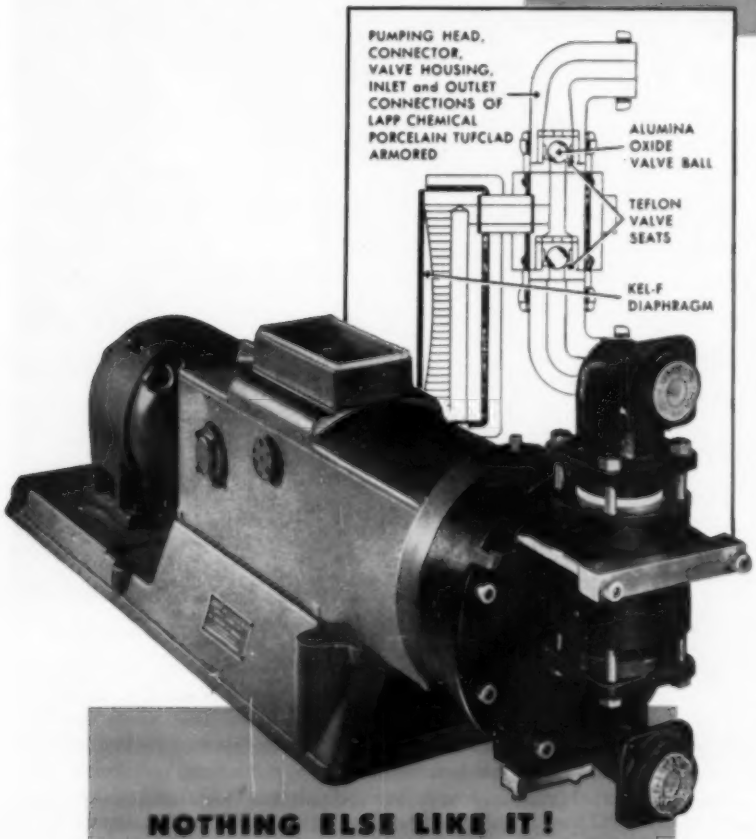
DILUTE ACIDS

MIXED ACIDS

WITH

Lapp PULSAFEEDER

COMPLETELY NON-METALLIC CONSTRUCTION


PUMPING HEAD, CONNECTOR, VALVE HOUSING, INLET and OUTLET CONNECTIONS OF LAPP CHEMICAL PORCELAIN TUFCLAD ARMORED
ALUMINA OXIDE VALVE BALL
TEFLON VALVE SEATS
KEL-F DIAPHRAGM

Solid Lapp Chemical Porcelain, combined with parts of alumina ceramic, teflon and Kel-F plastics, is used for the liquid end of this model of Lapp Pulsafeeder. All parts which can come in contact with liquid being pumped are non-metallic, chemically inert. Thus, positive-displacement metered pumping of "hard-to-handle" corrosive chemicals is made certain and permanently trouble-free.

NOTHING ELSE LIKE IT!

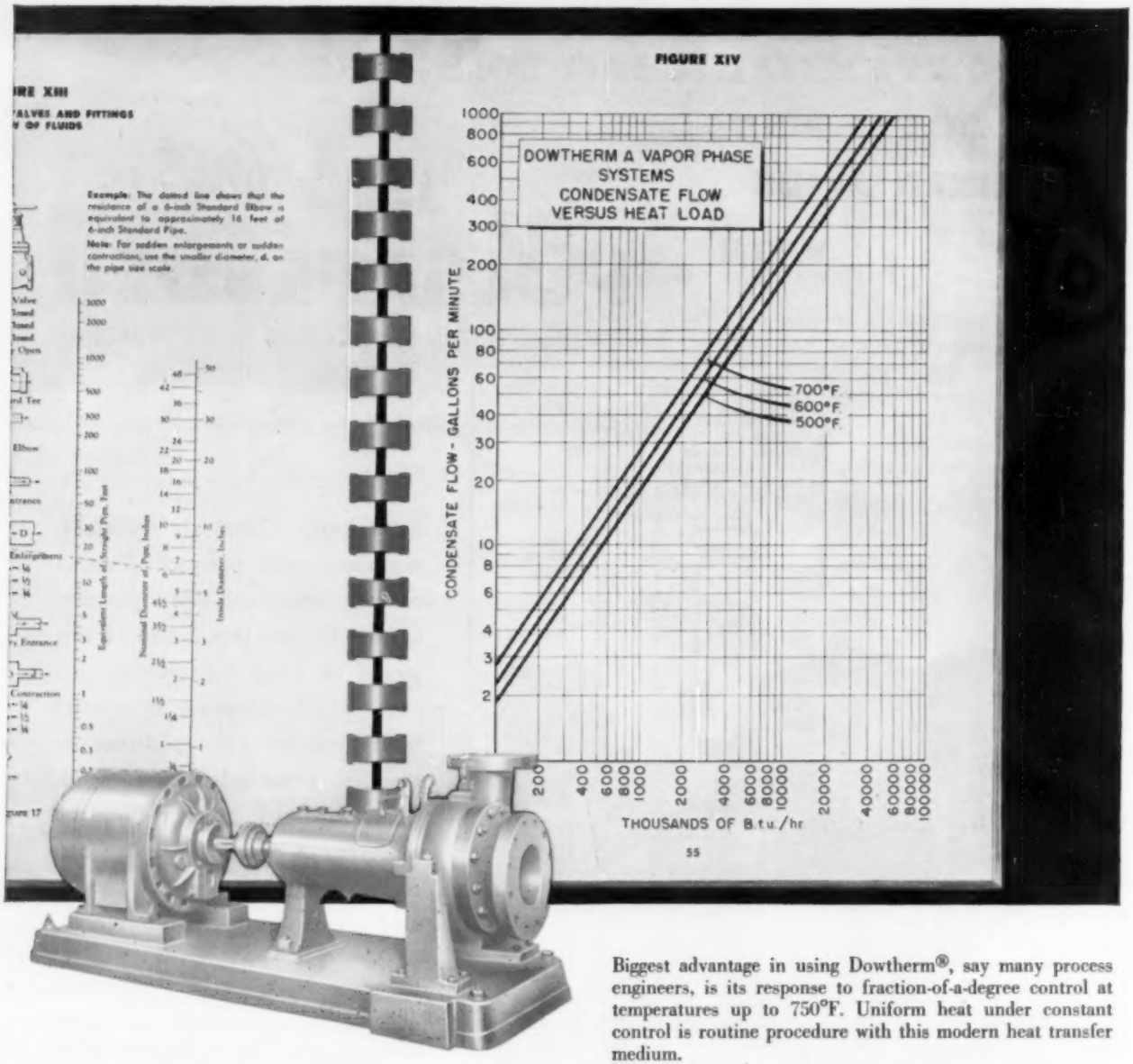
Lapp Pulsafeeder is the combination piston-diaphragm pump for controlled-volume pumping of fluids. Reciprocating piston action provides positive displacement. But the piston pumps only an hydraulic medium, working against a diaphragm. A floating, balanced partition, the diaphragm isolates chemical being pumped from working pump parts —eliminates need for stuffing box or running seal. Pumping speed is constant; variable flow results from variation in piston-stroke length—controlled by manual hand-wheel, or, in Auto-Pneumatic models, by instrument air pressure responding to any instrument-measurable processing variable.

WRITE FOR BULLETIN 440

with typical applications, flow charts, description and specifications of models of various capacities and constructions. Inquiry Data Sheet included from which we can make specific engineering recommendation for your processing requirement. Write Lapp Insulator Co., Inc., Process Equipment Division, 404 Wilson Street, Le Roy, New York.

DOW

Control Problems In Process Heat?



DOWTHERM

responds with fraction of a degree control to simple pressure regulation!

Biggest advantage in using Dowtherm®, say many process engineers, is its response to fraction-of-a-degree control at temperatures up to 750°F. Uniform heat under constant control is routine procedure with this modern heat transfer medium.

Dowtherm provides low-pressure, high-temperature heat, extending the advantages of vapor-phase heating to much higher temperatures. The extraordinary thermal stability of Dowtherm makes it a natural for those applications demanding liquid phase heating.

Many process industries have developed new products or improved old-line products by utilizing the unique properties of Dowtherm. You'll find all the facts in the "*Dowtherm Handbook*", a valuable technical guide of process heat information. A request on your letterhead will bring it to you promptly. THE DOW CHEMICAL COMPANY, Midland, Michigan, Dept. DO 727A.

you can depend on DOW CHEMICALS

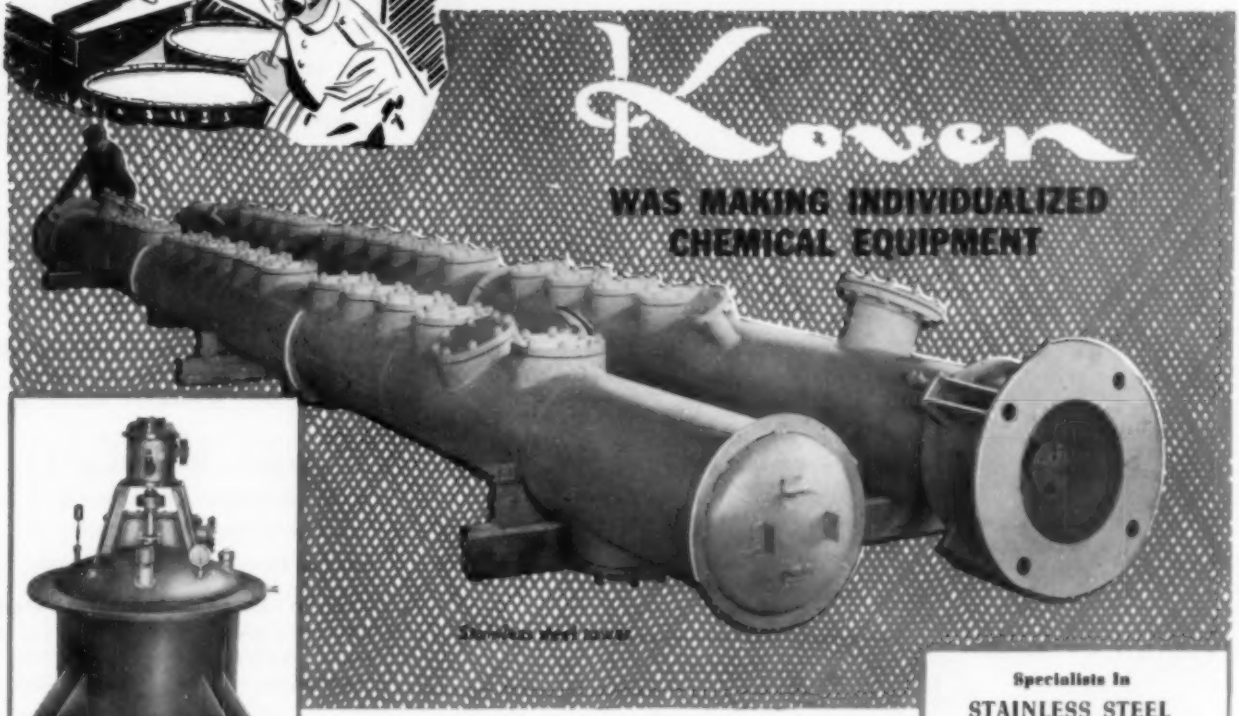
DOW

BACK IN THE 1880's

WHEN JOHN PHILIP SOUSA WAS LEADER OF THE MARINE BAND

Koven

WAS MAKING INDIVIDUALIZED CHEMICAL EQUIPMENT



Stainless steel tower

High pressure mixing vessel

Specialists In

STAINLESS STEEL
MONEL
NICKEL
ALUMINUM
INCONEL
ALL CLAD MATERIALS

FABRICATION TO ALL A.S.M.E. CODES.

Everyone loves a parade—and through the years Sousa's stirring marches have become as indispensable to an American parade as a brass band. Industry has its important names also—names such as KOVEN, famous in the chemical industry for over 70 years for expertly fabricated equipment.

KOVEN's skilled craftsmen build each unit to fit a specific operation; thereby rendering production more efficient and more profitable—a prime factor in these days of technical complexities and mounting costs. Follow the lead of top-ranking chemical manufacturers throughout the country. Let KOVEN help cut your production costs with smooth-functioning KOVEN equipment—built to your exact needs. Call or write for a consultation—of course, there is no obligation. Send for Bulletin #550.

X-RAY INSPECTION FOR QUALITY CONTROL.

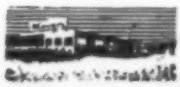
KOVEN equipment in all metals and alloys include: High pressure vessels, extractors, mixers, stills, kettles, tanks, stacks, breechings. Shop and field erected storage tanks. High vacuum testing.

L. O. KOVEN & BRO., INC.
154-F Ogden Ave., Jersey City 7, N.J.

Plants:

Jersey City, N. J.

Dover, N. J.



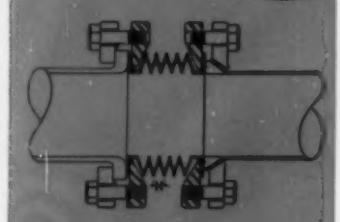
Trenton, N. J.

KOVEN FOR INDIVIDUALIZED EQUIPMENT SINCE 1881

Chemiseal Gaskets

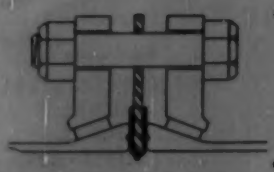
MADE OF TEFLON DuPont Trademark

and Accessories for Glass Piping

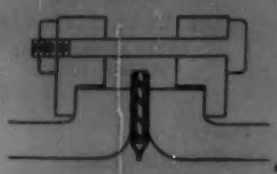


ABOVE: Chemiseal Snap-on Gaskets, molded of TEFLON to match contour of conical end glass pipe, assure perfect automatic centering of joints and free flow of materials. For all standard pipe sizes from ¼ in. to 6 in.

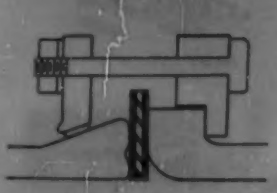
AT LEFT: Chemiseal Expansion Joints and Flexible Couplings absorb shock and vibration, thermal expansion and contraction. Correct misalignment. Connect unlike piping ends and nozzles.



Chemiseal TEFLON-Jacketed Gaskets, standard for Corning conical flanges. Seal at low bolt loads. Sizes from 1 in. to 6 in.



Chemiseal TEFLON-Jacketed Gaskets. Compressed asbestos sandwiched between woven asbestos inclosed in a TEFLON envelope. Ideal for glass-lined steel connections. Seal at low bolt loads.



Chemiseal Adaptors provide a safe, tight seal between unlike piping ends and nozzles. A steel bearing ring provides rigidity. Resilient core assures positive seal. TEFLON Jacket protects and contains easy-to-handle single unit.

WRITE FOR CATALOG NO. TG-953.

UNITED STATES GASKET COMPANY • CAMDEN 1, NEW JERSEY

USG

FABRICATORS OF FLUOROCARBONS & OTHER PLASTICS

Representatives in principal cities throughout the world

TECHNICAL PROGRAM

(*Continued from page 32*)

PREDICTION OF HEAT TRANSFER BURNOUT, L. Bernath, E. I. du Pont de Nemours and Company, Wilmington, Del.

CORRELATION OF MAXIMUM HEAT FLUX DATA FOR BOILING LIQUIDS, W. Rohsenow, and P. Griffith, M.I.T., Cambridge, Mass.

EFFECT OF AGITATION AT THE CRITICAL TEMPERATURE DIFFERENCE FOR A BOILING LIQUID, F. S. Pramuk, and J. M. Westwater, Univ. of Illinois, Urbana, Illinois.

HEAT TRANSFER IN THE CONDENSATION OF METAL VAPORS. MERCURY AND SODIUM UP TO ATMOSPHERIC PRESSURE, C. F. Bonilla, and B. Misra, Columbia Univ., New York, N. Y.

HEAT AND MASS TRANSFER DURING COOLING AND CONDENSATION OF SATURATED TITANIUM TETRACHLORIDE-NITROGEN MIXTURES, R. W. Schuler and J. B. Abell, Res. and Eng. Divs., Monsanto Chemical Company, Dayton, Ohio.

SIMULTANEOUS HEAT AND MASS TRANSFER IN PARTIAL CONDENSATION, E. Kent, and R. L. Pigford, Univ., of Delaware, Newark, Del.

Tuesday, March 22, 1955

TECHNICAL SESSION NO. 5

(Simultaneous with Session No. 6)

GENERAL PAPERS, R. M. Reed, Presiding.

MODIFIED LAW OF CORRESPONDING STATES, Oscar T. Bloomer; Eastman Kodak Co., Rochester, New York, and R. E. Peck, Illinois Institute of Gas Technology, Chicago, Illinois.

THE CONTINUOUS CATALYTIC HYDROCHLORINATION OF STYRENE, R. S. Montgomery, The Dow Chemical Co., Midland, Michigan.

FLOW OF NON-NEWTONIAN FLUIDS-CORRELATION FOR THE LAMINAR, TRANSITION AND TURBULENT FLOW REGIONS, A. B. Metzner and J. C. Reed, University of Delaware, Newark, Delaware.

RECOVERY OF ETHYLENE GLYCOL FROM SPENT ANTI-FREEZE SOLUTIONS, M. B. Glaser and George Thodos, Northwestern Technological Institute, Evanston, Illinois.

TECHNICAL SESSION NO. 6

(Simultaneous with Session No. 5)

A.I.Ch.E.—A.S.M.E. JOINT HEAT TRANSFER SYMPOSIUM, O. P. Bergelin, Presiding.

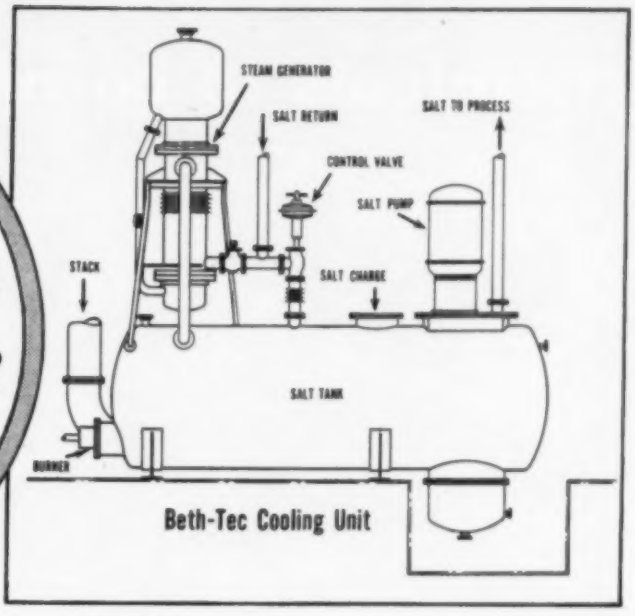
PROPERTIES OF EVAPORATED METAL FILMS RELATED TO THEIR USE FOR SURFACE TEMPERATURE MEASUREMENT, T. B. Simpson and C. C. Winding, Cornell Univ., Ithaca, N. Y.

DISTRIBUTION OF TEMPERATURE IN 1-2-PASS HEAT EXCHANGERS WITH SHELL-SIDE FLUID CHANGES IN PHASE AND TEMPERATURE, H. T. Bates, Univ. of Nebraska, Lincoln, Nebr.

(*Continued on page 64*)

Are you making

Phthalic Anhydride
Maleic Anhydride
Methyl Amines?



Beth-Tec Cooling Unit

or other chemicals with a high temperature reaction.

If so, it will pay you to use BETH-TEC® proved systems for high temperature heating and for cooling with molten salt.

Because they consist of elements proved in salt service, BETH-TEC systems have these advantages over systems individually designed by users:

- They are safer.
- They are less costly.
- Their operation is trouble-free.
- Their maintenance is lower.

BETH-TEC systems provide liquid heat and/or cooling at no pressure, in the range from 650° to 1000°F.

The heat transfer salt (duPont Hi-Tec) is an efficient thermal medium. It is non-toxic, non-corrosive, non-fouling, chemically-stable and inexpensive.

Will you risk safety, have higher initial and maintenance costs, and have troublesome operation with an individually designed unit; or will you have BETH-TEC — the complete, efficient package heat transfer system.

Take advantage of our experience and complete facilities. Let us relieve you of engineering and fabrication. Use the BETH-TEC system. It will pay you better at the start—and over the years.

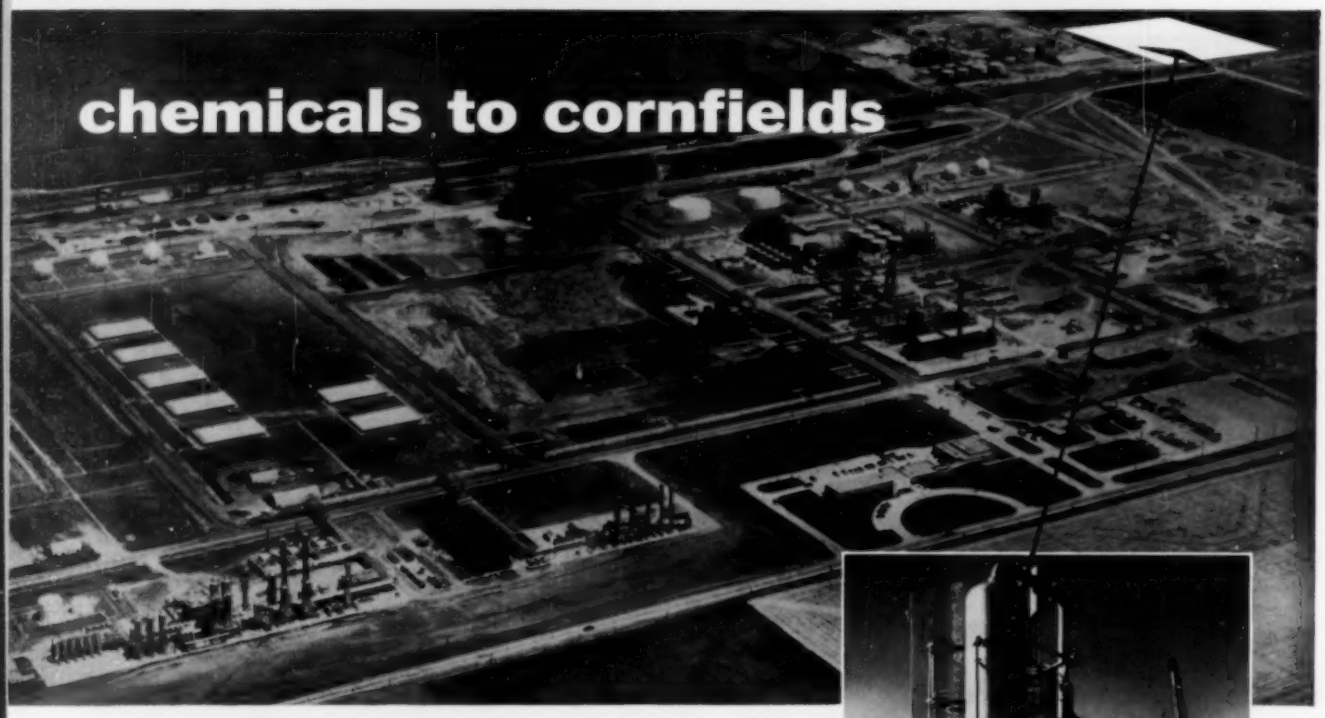
USE COUPON FOR FULL DETAILS

BETHLEHEM FOUNDRY & MACHINE CO.
Process Equipment Division
BETHLEHEM PENNSYLVANIA

BETHLEHEM FOUNDRY & MACHINE COMPANY
BETHLEHEM, PENNSYLVANIA

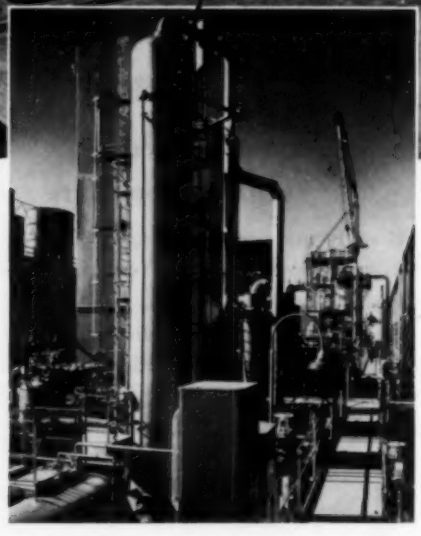
Please send me descriptive folder regarding BETH-TEC units.

Name.....
Firm.....
Street.....
City.....State.....



new USI ammonia and nitrogen solutions plant at Tuscola

by John B. Mellecker



"From cornfields to chemicals" was the theme of the original dedication, barely a year ago, of the vast Tuscola works of National Petrochemical Corp., the manufacturing firm owned jointly by National Distillers and Panhandle Eastern Pipeline.

At a recent dedication of the new ammonia and nitrogen solutions plant adjacent to Petro's Tuscola works, the theme might have been, in reverse, "from chemicals to cornfields."

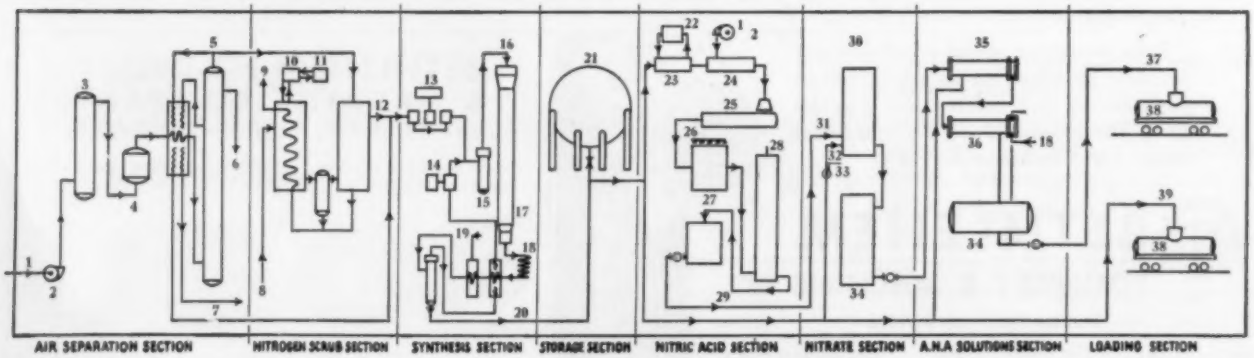
Originally benefiting the economics of central Illinois, this latest addition to the sprawling petrochemical outlay at Tuscola will make available plenteous quantities of nutrient to enhance the near-by farm land—which is among the world's richest.

Mechanization Anomaly

Why, in the heart of black-loam country, a fertilizer plant can expect to thrive is best explained by an Illinois agronomist, who ascribes this modern phenomenon to farm mechanization. In replacing the horse, the tractor has not directly created a fertilizer shortage—at least in this part of the country, where

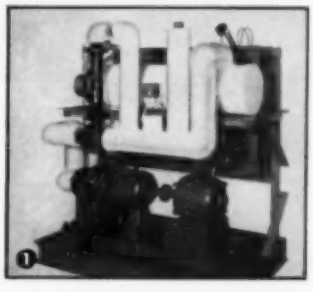
(*Continued on page 74*)

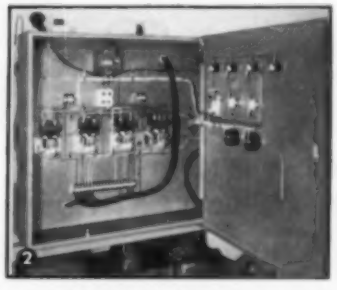
1. Air; 2. Turbo compressor; 3. Caustic scrub tower; 4. Air dryer; 5. Air separation column; 6. Argon for purification and sale; 7. Oxygen for captive use; 8. Impure H_2 from P.C.C.; 9. To fuel gas; 10. Ethlene ref.; 11. NH_3 ref.; 12. H_2; 13. Primary compressor; 14. Circulator; 15. Oil separator; 16. Converter; 17. Rain cooler; 18. Water; 19. NH_3 ref.; 20. Product NH_3; 21. Ammonia storage; 22. Heat; 23. Vaporizer; 24. Mixer; 25. Heat exchanger; 26. Water; 27. Cooler; 28. Condensate; 29. Nitric acid to ammonium nitrate; 30. Neutralizer; 31. HNO_3; 32. NH_3; 33. Steam; 34. Storage; 35. Mixer; 36. Cooler; 37. A.N.A. solutions to tank cars; 38. Tank car; 39. Ammonia to tank cars and trucks.



A COMPLETE TRANSFER OIL HEATING SYSTEM in one compact "PACKAGE"

Instruments and controls are substantially flush mounted. Temperature controls are carefully selected to maintain oil supply temperature within 2° C. Signal lights confirm satisfactory operation.





1. The system is compactly arranged to conserve space. To obviate leaks, pipe connections are welded wherever possible. The heavy pipe insulation is securely wired and wrapped with cemented canvas.

2. The workmanlike electrical system provides easy-to-trace circuits. All wire of high current capacity is heavy cross section.

WHITLOCK has developed a standard "package", with ratings of 10 to 50 KW, which includes heater operating controls and expansion tank to heat chemically stable transfer oils. Since these oils are liquid over considerable temperature ranges, they are being used increasingly in chemical processing operations. The heating equipment, previously of special design, is now available as a complete, standardized unit to which only oil and electrical connections need be made in order to permit immediate operation.

The combination of low liquid pressures and high liquid temperatures eliminates the need for the application of high pressure design techniques to many current processes. This new "package" effectively serves to reduce overall equipment costs and to simplify process design.

For additional information and prices, write The Whitlock Manufacturing Company, 97 South Street, West Hartford 10, Conn. In Canada: Darling Brothers, Ltd., Montreal.

Whitlock

Designers and builders of heads, coils, condensers, coolers, heat exchangers, heaters, piping, pressure vessels, receivers, reboilers.

BLUEGRASS COUNTRY

(*Continued from page* 34)

At 6:30 p.m. on this busy *Tuesday*, there will be a reception prior to the banquet. Then at 7:30, the banquet, which will be held in the Flag room. Leave the Tux at home, as the approved male costume will be informal.

Speaker at the banquet will be Mark F. Ethridge, publisher, The Courier-Journal and The Louisville Times.

Special for the ladies . . .

In addition to the previously described events, three special events have been arranged as being of particular appeal to the ladies. At 11:15 *Monday* a trip will get under way to a "color in your home" luncheon to be presented by the Kurfees Paint Co. A competent interior decorator will conduct a discussion which will wind-up with a trip through the plant.

On *Tuesday* at 10:00, buses will leave for a tour of Kentucky landmarks, including Lincoln's birthplace, the University of Louisville, and Churchill Downs. A drive *past* the gold vault at Ft. Knox is promised. Luncheon will be served at historic Talbott Tavern in Bardstown.

Wednesday will provide a luncheon at Old House, in a truly distinctive and leisurely manner—followed by a "different style show."

Plant trips

Diversity is probably one of the most important features of industry in Louisville. It is one of the few cities in the country with factories representing each of the twenty industrial groups listed in the U. S. Census. The growth of the Louisville chemical industry has been particularly striking—a six-fold increase in employment in chemical plants between 1939 and 1953. The plant trip program discussed below is designed to show both diversity and growth. For those, however, who missed the last Louisville meeting or who were unable to make the trips, some old favorites are included. Of course, these include distilling, Louisville's oldest chemical industry. Those of you interested in history will find much source material in the story of charred oak barrels and the close ties between distilling and early settlement. In addition, manufacture of chemical rubber, although not having the extent of background found in distilling, has been an important part of the Louisville scene since 1941. In an area directly outside the city limits known as Rubbertown, the visitor to the Spring Meeting will have an opportunity to see GR-S polymerization and the integrated production of neoprene from acetylene. Other industries included are: processing of natural gas by-products and manufacture of detergents, finishes, electrical appliances and metal products. The production of electrical appliances in General Electric's huge Appliance Park is one of the recent and most powerful influences in Louisville industry. Nearing completion, the plant will be the center of all of the company's activities concerned with major appliance manufacture and distribution. With an eventual employment of about 16,000 people, it will be the largest electrical appliance plant in the world. The Olin Mathieson operation at Brandenburg should be of interest as an example of modern chemical plant construction (it is only three years old) and as an illustration of the trend toward pipeline receipt of raw materials from the petroleum industry.

...even under extreme conditions!

BARTON DP TRANSMITTERS accurately transmit flow, liquid level, and/or differential pressure with high speed, high sensitivity and low air consumption, regardless of temperature variation, pulsation, and severe over-range. Direct mechanical indicator insures continuity of operation on air failure; and together with accessible adjustments, simplifies field calibration. **For further information request bulletin 214-1 or contact BARTON sales engineers, located in most principal cities.**

TURNING OPERATIONS ON BARTON FLOWMETER BODY HEADS

Differential pressure ranges from 20 "WC to 400" WC. Pressures to 4500 psi. Static pressure pen is optional.

MODEL 202 RECORDER

BARTON INSTRUMENT CORPORATION
INDUSTRIAL INSTRUMENTS
1429 SOUTH EASTERN AVENUE · LOS ANGELES 22, CALIFORNIA

LION OIL COMPANY

LION

EL DORADO, ARKANSAS

J. B. ROGERSON,
MANAGER OF MANUFACTURING

MANUFACTURING DIVISION

October 29, 1954

LUMMUS

DATE REC'D:	NOV. 1, 1954
ROUTE TO:	C.A.B.
REMARKS:	

Mr. C. A. Barrere
Vice President
The Lummus Company
2707 Weslayan
Houston 6, Texas

Dear Mr. Barrere:

The construction of our chemical plant in St. Charles Parish, Louisiana, to produce 300 tons per day of ammonia, 450 tons per day of nitric acid, and 550 tons per day of ammonium nitrate pellets was completed by your company June 1, 1954, and was well within labor cost and time allocated to this project.

Please extend our sincere compliments to all of the people in your organization who worked on this project for a job well done.

Yours very truly,

LION OIL COMPANY

J. B. Rogerson
Manager of Manufacturing

JBR:mpd

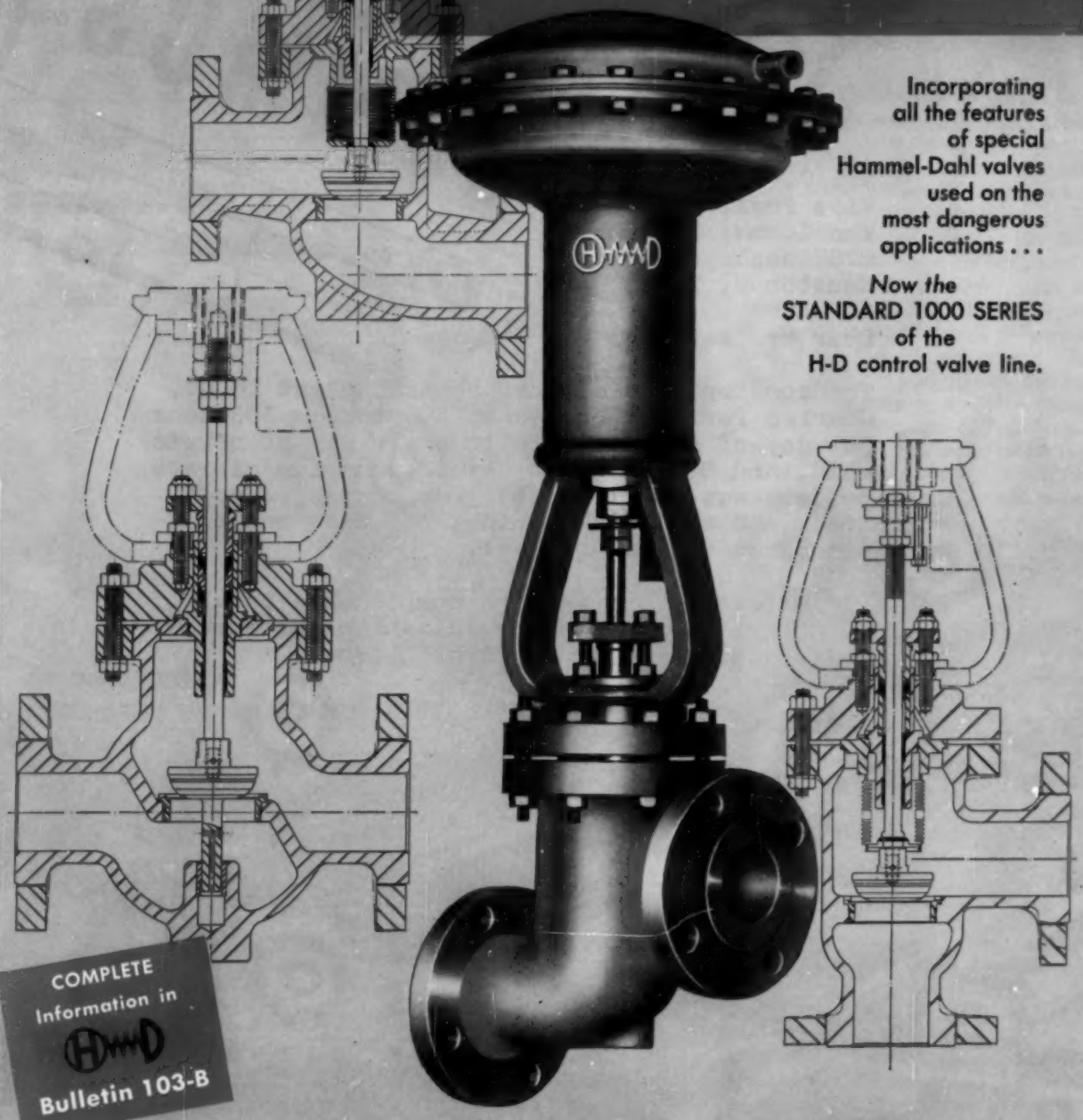
Illustrated: The Lion Oil Co. chemical plant constructed by Lummus in St. Charles Parish, Louisiana

Lummus has recently been awarded the contract to engineer and construct a 60-ton/day ammonia plant for Wellman's Chemical Division of Food Machinery and Chemical Corporation.

"Ne Plus Ultra"

OF PROCESS CONTROL

THE *Ultravalve*



Incorporating all the features of special Hammel-Dahl valves used on the most dangerous applications . . .

Now the STANDARD 1000 SERIES of the H-D control valve line.

COMPLETE Information in Bulletin 103-B

HAMMEL-DAHL COMPANY

175 POST ROAD, (WARWICK) PROVIDENCE 5, R. I., U. S. A.

SALES OFFICES IN ALL PRINCIPAL CITIES

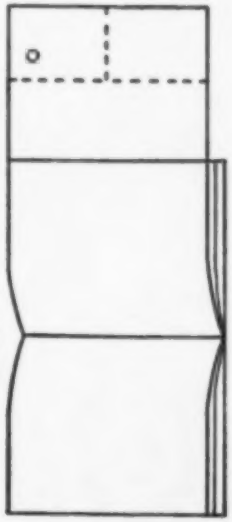
MANUFACTURING PLANTS IN WARWICK, R. I., U. S. A., CANADA, ENGLAND, FRANCE AND HOLLAND

CANADIAN MANUFACTURING AFFILIATE—GUELPH ENGINEERING CO., GUELPH, ONT.

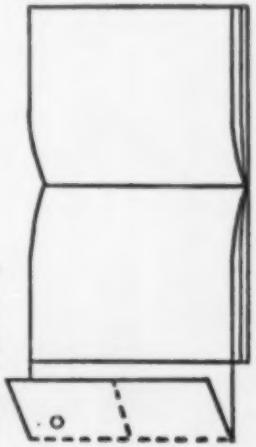
for your information

This C.E.P. information service is a convenient way to get the chemical engineering information you need on the new equipment, an advertised products, on the newly announced developments reported on these pages. A one post card inquiry designed to bring data quickly and easily. Circle the items of interest, sign your name, position, address, etc., and drop in the mail.

Just a moment is needed to learn how to use this insert. When looking through the front part of the magazine pull the folded portion of the insert out to the right, and the numbers on the post card are convenient for marking. THEN . . . .



as you pass the pull-out page, and it is on the left, fold the post card back along the vertical scoring, and once again the numbers are handy for circling.



Postage Will Be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD

First Class Permit No. 48890, Sec. 34.9, P. L. & R., New York, N. Y.

CHEMICAL ENGINEERING PROGRESS
25 West 45th Street
New York 36,
New York

Postage Will Be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD

First Class Permit No. 48890, Sec. 34.9, P. L. & R., New York, N. Y.

CHEMICAL ENGINEERING PROGRESS
25 West 45th Street
New York 36,
New York

PRODUCTS

IFC **Urea.** Inventa urea process increases potentialities of production for fertilizers, cattle feeds, plastics. Provides top-quality product. Vulcan Copper & Supply Co.

3R **Feeders.** For safe operation at maximum efficiency, without danger of overloading sifters, grinders, elevators, Draver Feeders. B. F. Gump Co.

4A **Valves.** Corrosion control, long life, tighter seal, feature these valves. Also available are lubricants for every combination of needs. Rockwell Mfg. Co.

6L **Verti-Line Pumps.** Turbine pumps made to highest standards of quality control in new, ultra-modern factory. Layne & Bowler Pump Co.

7A **Steam Traps.** Six types for every process, heat, power use, ¼ to 2 in. sizes for pressures from vacuum to 300 lb. W. H. Nicholson & Co.

8A **Valves.** Crane No. 1610 packless diaphragm valves for problems with hard-to-hold fluids. Crane Co.

9A **Sulfur Plants.** Engineering services available for design, erection, & operation of sulfur recovery plants. Ralph M. Parsons Co.

10L **Proportioning Pumps.** Convenient, versatile proportioning pumps offering precision operation. Easy to install U pump. Hills-McCanna Co.

11A **Impervious Graphite Equipment.** Karbate impervious graphite inert to wide range of corrosive conditions for new construction or expansion. National Carbon Co., Div. Union Carbide and Carbon Corp.

12A **Plastic Equipment.** Corrosion-resistant cooling towers, fume ducts, tanks, covers, pipe of laminated polyester glass. Haveg Corp.

13A **Fertilizer Pellets.** Complex fertilizer pellets containing balanced quantities of nitrogen, phosphorus & potash. Chemical and Industrial Corp.

14L **Drying Equipment.** Service available to aid in selection of drying equipment & solution of materials handling problems. Proctor & Schwartz, Inc.

15A **Flow Colorimeter.** Color intensity, turbidity, chemical composition continuously monitored & evaluated with this new instrument. Beckman Instruments, Inc.

16A **Control Device.** Dewcel provides simple way to measure dew point directly, accurately, continuously. Foxboro Co.

17A **Nuclear Energy.** Practical answers on industrial applications supplied. Blaw-Knox Co.

18A **Hard Rubber.** Ace Tempron a new synthetic hard rubber for chemical equipment. Offers good chemical resistance for high temperature applications. American Hard Rubber Co.

19R **Centrifugal Pump.** Type SVS a new, simplified single stage centrifugal pump for the process industries. See bulletin 121. Pacific Pumps, Inc.

20A **Thermal Insulation.** A complete insulation engineering service assures maximum return on insulation investment. Johns-Manville.

21A **Process Equipment.** Pressure filters, heat exchangers, ion exchange units, other equipment for chemical process industries. Industrial Filter & Pump Mfg. Co.

22A **Tubing.** Pressures 100,000 lb./sq.in. achieved to insure good working conditions at 30,000 lb./sq.in. by advance in manufacturing techniques. Babcock & Wilcox Co.

23A **Chromate Disposal.** Installation of Permutit ion exchange units solves waste disposal problems. Permutit Co.

24A **Anhydrous Hydrogen Chloride.** Design, building, licensing of plants for manufacture of hydrogen chloride available. Girdler, Div. of National Cylinder Gas Co.

26A **Hydrocarbon Separation.** The low temperature route for hydrocarbon separation explored in brochure. Engineering analysis, or complete process design available. Air Products, Inc.

27A **Valves.** Corrosion-resistant valves in wide variety of metals & alloys & all designs. Wm. Powell Co.

28A **Process Equipment.** Piping, pressure vessels, heat exchangers, other equipment requiring pressure & temperature considerations designed & fabricated. M. W. Kellogg Co.

29A **Flaking.** Controlled supercooling with Votator heat transfer apparatus produces better crystal structure. Girdler Co., Div. National Cylinder Gas Co.

31A **Valves.** Precision grinding of solid porcelain valves with silicon carbide wheels achieves close dimensional tolerances. Lapp Insulator Co., Inc.

32A **Ammonia Synthesis.** Simple, dependable synthesis method for producing liquid anhydrous ammonia. Foster Wheeler Corp.

33A **Air Preheater.** Comparative fuel & power costs for operating two stills one with the Ljungstrom preheater reflect operational savings. Air Preheater Corp.

35A **Pulsafeeder.** Unit is the combination piston-diaphragm pump for controlled-volume pumping of fluids. Completely non-metallic construction. Lapp Insulator Co., Inc.

36A **Dowtherm.** Response within fraction of a degree control to simple pressure regulation, at temperatures to 750° F. Dow Chemical Co.

37A **Chemical Equipment.** Individualized chemical equipment fabricated by specialists in stainless steel, Monel, nickel, all clad materials. L. O. Koven & Bro., Inc.

38L **Gaskets.** Chemiseal gaskets & accessories for glass piping molded of Teflon, match contour of pipe. United States Gasket Co.

39A **Beth-Tec Units.** Complete facilities for engineering & fabrication of systems for high temperature heating & cooling with molten salt. Bethlehem Foundry & Machine Co.

41A **Oil Heating System.** A compact transfer oil heating system with ratings 10 to 50 k.w. Whitlock Mfg. Co.

42BL **Transmitters.** For accurate transmission of flow, liquid level, units give successful performance under extreme conditions. Barton Instrument Corp.

43A **Design & Engineering Services.** Specialists in design, erection, & operation of ammonia & other chemical plants. Lummus Co.

44A **Valves.** Standard 1,000 series of process control valves for most dangerous applications. Hammel-Dahl Co.

Chemical Engineering Progress

Numbers followed by letters indicate advertisements, the number corresponding to the page carrying the ad. This is for ease in making an inquiry as you read the advertisements. Letters indicate position—L, left; R, right; T, top; B, bottom; A indicates a full page; IFC, IBC, and OBC are cover advertisements.

Be sure to give name, address, position, etc.

Remember, the numbers on the upper portion of the card bring you data on only the bulletins, equipment, services, and chemicals reported in these information insert pages. The lower portion of the card is for the advertised products, and is keyed not only to advertising pages, but also to the memory-tickling list under the heading Products.

49A Twin Shell Blenders. Faster efficient blending of dry materials with p-k twin shell blenders. Patterson-Kelley Co., Inc.

52A Flow Control Approach. Controlled volume pumps act as control instruments. Guard product quality in continuous polymerization. Milton Roy Co.

52AF Tower Packing. Savings in gas pumping costs with use of Intalox saddle tower packing. Original low pressure drops maintained. U. S. Stoneware Co.

57A Pulverizer. Facilities available for solution of any pulverizing problem. Schutz-O'Neill Co.

58L Valves. Available for solution of metals valves for handling materials from acetic acid through ethylene glycol & potassium dichromate to zinc sulphate. DeZurik Shower Co.

58BR Portable Filter. For use in filtering & filling in small plant or batch lots. Pharmaceuticals, cosmetics, chemicals, etc. Ertel Engineering Corp.

59A Graphite Anodes. Performance of GLC anodes in electrolytic cell operations recommends their use by chlor-alkali producers. Great Lakes Carbon Corp.

60BL Repair Services. An expert repair crew available at any hour of day or night for instrument repair, retubing, other needs. Condenser Service & Engineering Co., Inc.

61A Extractors. Multi-stage liquid-liquid extractors improve efficiency, economy of solvent extraction. For laboratory, pilot plant, or industrial use. York Process Equipment Corp.

(Continued on back of this insert)

Please do not use this card after May, 1955

1	2	3	4	5	6	7	8	9	10	11	12	14	15
16	17	18	19	20	21	22	23	24	25	26	27	28	29
30	31	32	33	34	35	36	37	38	39	40	41	42	43
44	45	46	47	48	49	50	51	52	53	54	55	56	57
58	59	60	61	62	63	64	65	66	67	68	69	70	71
72	73	74	75	76	77	78	79	80	81	82	83	84	85
86	87	88	89	90	91	92	93	94	95	96	97	98	99
100	101	102	103	104	105	106	107	108	109	110	111	112	114
115	116	117	118	119	120	121	122	123	124	125	126	127	128

Advertisers' Products

IFC	3R	4A	6L	7A	8A	9A	10L	11A
12A	13A	14L	15A	16A	17A	18A	19R	20A
21A	22A	23A	24A	26A	27A	28A	29A	31A
32A	33A	35A	36A	37A	38L	39A	41A	42BL
43A	44A	49A	52A	52AF	57A	58L	58BR	59A
60BL	61A	62L	63A	64L	65A	66L	67A	68L
69A	70L	71A	72TL	72BL	73A	74L	75A	76R
77R	78L	78R	79R	80L	81R	82BL	83R	84L
85R	86TL	86BL	87L	87R	88L	89R	90L	91R
92TL	92BL	93R	94L	94R	95R	96BL	97TR	97BR
98TL	98BL	99TL	99BL	99R	101R	102TL	102BL	103BR
IBC	OBC							

Chemical Engineering Progress Data Service

Name .....

Position .....

Company .....

Address .....

City .....Zone.....State .....

☐ I want a subscription. Bill me $6.00 for a year.

February, 1955

Please do not use this card after May, 1955

1	2	3	4	5	6	7	8	9	10	11	12	14	15
16	17	18	19	20	21	22	23	24	25	26	27	28	29
30	31	32	33	34	35	36	37	38	39	40	41	42	43
44	45	46	47	48	49	50	51	52	53	54	55	56	57
58	59	60	61	62	63	64	65	66	67	68	69	70	71
72	73	74	75	76	77	78	79	80	81	82	83	84	85
86	87	88	89	90	91	92	93	94	95	96	97	98	99
100	101	102	103	104	105	106	107	108	109	110	111	112	114
115	116	117	118	119	120	121	122	123	124	125	126	127	128

Advertisers' Products

IFC	3R	4A	6L	7A	8A	9A	10L	11A
12A	13A	14L	15A	16A	17A	18A	19R	20A
21A	22A	23A	24A	26A	27A	28A	29A	31A
32A	33A	35A	36A	37A	38L	39A	41A	42BL
43A	44A	49A	52A	52AF	57A	58L	58BR	59A
60BL	61A	62L	63A	64L	65A	66L	67A	68L
69A	70L	71A	72TL	72BL	73A	74L	75A	76R
77R	78L	78R	79R	80L	81R	82BL	83R	84L
85R	86TL	86BL	87L	87R	88L	89R	90L	91R
92TL	92BL	93R	94L	94R	95R	96BL	97TR	97BR
98TL	98BL	99TL	99BL	99R	101R	102TL	102BL	103BR
IBC	OBC							

Chemical Engineering Progress Data Service

Name .....

Position .....

Company .....

Address .....

City .....Zone.....State .....

☐ I want a subscription. Bill me $6.00 for a year.

February, 1955

PRODUCTS (*Continued*)

62L **Packing.** Lattice Braid packing fabricated from variety of materials including Teflon said to withstand wear beyond normal limits. Garlock Packing Co.

63A **Filter.** Effortless operation features the MCR filter. Easy cleaning & closing, self-sealing cover gasket. Sparkler Mfg. Co.

64L **Teflon.** Chemically inert, material resists heat & cold, is nonadhesive, has good flexural strength. For fabricating parts, special shapes. Ethylene Chemical Corp.

65A **Corporation Briefs.** News about conference of design engineers, the new valve catalog which is ready, & an advanced know-how series of case histories. Cooper Alloy Corp.

66L **Wire Cloth.** Anti-corrosive wire cloth made from variety of materials for filter cloth, special parts, screens. Newark Wire Cloth Co.

67A **Process Plants & Units.** Building of many process plants, complemented by experience in other important engineering services in the petroleum, pertochemical, & chemical fields. Badger Mfg. Co.

68L **Alkyd Resin Plants.** Process plants designed, engineered, constructed, installed. Specialities include plants for fats & oils. Industrial Process Engineers.

69A **Celite.** Filter cake protected by 2,500,000 filter channels per square inch of surface. Recommended for critical purity required in antibiotics. Johns-Manville.

70L **Moisture Content Control.** System provides any temperature & relative humidity required. Makes humidity control a separate function. Niagara Blower Co.

71A **Evaporators.** Crystallizing, evaporating, & filtering problems simplified by use of Conkey designed & engineered equipment. Chicago Bridge & Iron Co.

72TL **Spray Booths.** Centri-Merge spray booths are designed & engineered for exacting operational requirements. Efficient, safe, clean. Schmieg Industries, Inc.

72BL **Bubble Caps.** Bulletin 21 on bubble caps contains compilation of engineering data, lists 200 styles available without die cost. Pressed Steel Co.

73A **Pumps.** New Power-Pac pumps have sectional fluid-end design. Plunger diameters 2½ to 11/32 in. for pressures 390 to 20,700 lb./sq.in. Aldrich Pump Co.

74L **Plastic Pumps.** Flex-i-liner pumps for handling difficult corrosion solutions & abrasive slurries. No metal in contact. Vanton Pump & Equipment Corp.

75A **Vacuum Drying.** Laboratory & pilot plant facilities for testing vacuum drying of products having drying difficulties. F. J. Stokes Machine Co.

76R **Comparators.** Determinations on pH, chlorine, phosphate, or nitrate made in three easy steps. Color standards guaranteed. W. A. Taylor and Co.

77R **Process Equipment.** Fabrication of kettles, boilers, reactors, or other process equipment. Manning & Lewis Engineering Co.

78L **Antifoam Emulsion.** Antifoam A said to be effective at remarkably low concentrations against many foamers. Dow Corning Corp.

78R **Pla-Tank Hood.** Molded from long-life, resin-bonded glass fibre laminate, resistant to wide variety of fumes & temperatures. Chemical Corp.

79R **Vapor Condenser.** A standard stainless steel vapor condenser to meet exacting requirements of chemical & process industries. Doyle & Roth Mfg. Co., Inc.

80L **Filters.** String filters said to assure 21 ft. of unbroken filter cake 24 hr. a day. Pilot plant filters available on rental basis. Filtration Engineers, Inc.

81R **Pump.** An all-Teflon & stainless steel pump handling 70% of corrosive chemical requirements. For laboratory, pilot plant, or small volume pumping in production. Eco Engineering Co.

82BL **Adsorption.** Florex an effective adsorption material available in particle sizes 2/4 to 200/up. Floridin Co.

83R **Flow Meters.** Greater accuracy assured when acids, caustics, & suspensions at high or low temperatures & pressures are measured with electronic flow meters. Potter Aeronautical Co.

84L **Tube Cleaners.** Rotojet junior tube cleaners for use in tubes ½ to 2 in. Unusually powerful. Elliott Co.-Roto Div.

85R **Alloy Steel Pipe.** Large O.D. alloy steel pipe for specialized uses such as oil refineries, & power stations. Posey Iron Works, Inc.

86TL **Pumps.** For big or little pumping jobs & abusive applications. No stuffing box, no submerged bearings. Nagle Pumps, Inc.

86BL **Nozzles.** Full or hollow cone, flat spray nozzles described & illustrated in catalog. Write Spray Engineering Co.

87L **Jet Mixer.** A jet mixer giving complete circulation. Has no vortex. For immiscible liquids. Hermas Machine Co.

87R **Vaporizers.** Standard designs—vertical & horizontal, for ammonia, chlorine, or propane, in wide capacity range. Richard M. Armstrong Co.

88L **Slime Control Equipment.** To combat slime problems in hot or cool water for makeup, process or other uses, slime control equipment. Wallace & Tiernan.

89R **High Alloy Castings.** Large or small castings from Duraloy. For heat, corrosion & abrasion resistance. Duraloy Co.

90L **Liquefied Gases.** Designers of liquefiers and manufacturers of laboratory & industrial plants to meet individual requirements. Herrick L. Johnston, Inc.

91R **Heat Exchangers.** Aerofin exchangers provide extended surface. High efficiency, long service life. Aerofin Corp.

92TL **Separators.** Process equipment for crushing, grinding, pulverizing, classifying, other operations solved by review of available literature. Bauer Bros. Co.

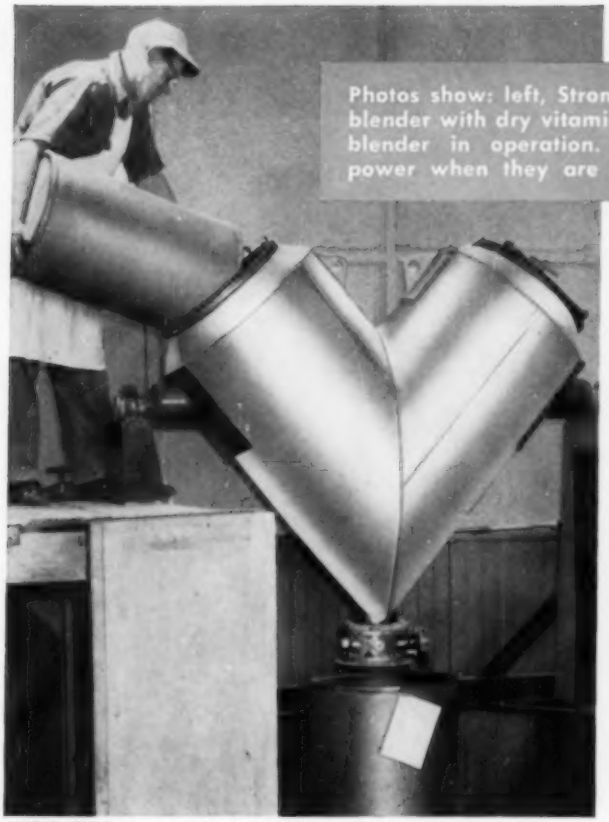
92BL **Portable Mixers.** For mixing, blending, dissolving applications, portable mixers sizes 1/20 to 7½ h.p. Alsop Engineering Corp.

93R **Junior Size Dryer.** New junior size dryer for pilot plants, laboratories, & schools. Air velocity 0 to +1,000 ft./min. C. G. Sargent's Sons Corp.

94L **Ion Exchange.** Getting good soft water depends on experienced engineering a feature of Illco-Way products. Illinois Water Treatment Co.

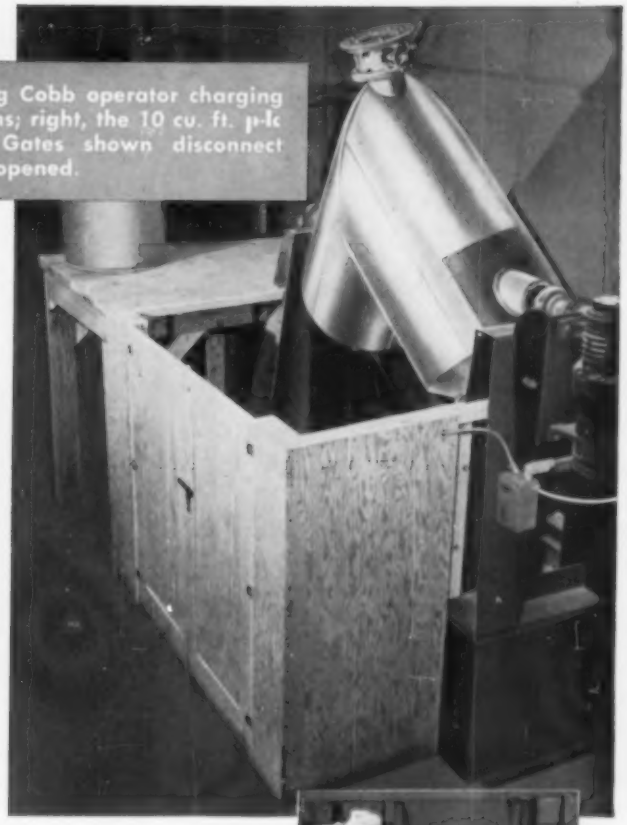
94R **Heat Exchangers.** Rugged construction & operational accessibility provide sustained performance of chemical process industry equipment. Davis Engineering Corp.

(Continued on page 50)



Photos show: left, Strong Cobb operator charging blender with dry vitamins; right, the 10 cu. ft. p-k blender in operation. Gates shown disconnect power when they are opened.

UNITED PRESS



How STRONG COBB & CO. CUT DRY BLENDING TIME 90%

Dry ingredients blend thoroughly and uniformly in **p-k** twin shell blenders* in only 1/10 the time required by other dry blenders, according to Strong Cobb & Co., Inc., Cleveland. They also pointed out that **p-k** twin shell blenders are much easier to clean than other blenders.

Strong Cobb manufactures drugs and pharmaceuticals to private formulas. Thorough blending, consistant uniformity from batch to batch, and clinical cleanliness are, of course, all-important to such products.

"We would recommend the twin shell blenders to others," say Strong Cobb. "For all types of mixes, they are fast, clean and positive. Loading and unloading is quick and easy."

Your mixing operation may call for a standard **p-k** twin shell dry blender, screw-feed or intensifier model. Perhaps a double cone or ribbon blender may be right for you. Because **p-k** manufactures all three kinds, you can be sure of impartial information to help you select the right blender to fill your needs.

Write now for Catalog No. 12, which includes complete engineering data —or send samples of materials for analysis of blending.

* Patented

"Cleaning is no problem," according to Strong Cobb. Here a worker washes out a 50-cu. ft. **p-k** blender. Twin shell blenders have no inside baffles to trap material.

simply designed for better blending

The Patterson-Kelley Co., Inc.

1720 Lackawanna Ave., East Stroudsburg, Penna.

2635

101 Park Avenue, New York 17 • Railway Exchange Building, Chicago 4 • 1700 Walnut Street, Philadelphia 3 • 96-A Huntington Avenue, Boston 16 • and other principal cities.

PRODUCTS

(Continued from page 48)

95R **Oxygen Analyzer.** Instrument now has convenient meter on door. Provides readings at sample point. Incorporates complete analyzing, calibrating & indicating components. Arnold O. Beckman, Inc.

96BL **Laboratory Stirrers.** Explosion proof air stirrers powered for air for safe, efficient, economical operation. Ace Glass, Inc.

97TR **Ejectors.** Trouble-free vacuum production assured with use of I-R steam-jet ejectors. Ingersoll-Rand Co.

97BR **Rotary Presses.** For high production at low cost, rotary presses with capacities 65 to over 5,000 tablets/min. Also mixers, granulators, & ovens. Arthur Colten Co.

98TL **Compressors.** Oilfreair & Oilfregas compressors are guaranteed to compress air & gas free of oil or oil vapor. Pennsylvania Pump and Compressor Co.

98BL **TankoMeter.** Instrument for measuring tank content at any distance point whether buried, elevated, open or closed. Uehling Instrument Co.

99TL **Process Equipment.** Specialists in fabrication of process equipment from stainless steel, Monel, Inconel, nickel, & aluminum. Alloy Fabricators.

99BL **Research Facilities.** Product development & improvements, process & packaging evaluation are only a few of facilities included in Snell research. Foster D. Snell, Inc.

99R **Filter Paper.** E&D No. 613 a filter paper for laboratory or industrial use for filtration of wide range of substances. Samples available. Eaton-Dikeman Co.

101R **Double Cone Blender.** Ten features of these units listed & detailed. General Machine Co. of New Jersey

102TL **Aerating Units—Bin Level Indicators.** Unit provides steady flow of dry, finely ground materials. Indicator signals change in level. Bin-Dicator Co.

102BL **Tanks.** Corrosion resistant & electrically insulative tanks. Available to your specifications in any shape or size from laminates. Carl N. Beetle Plastics Corp.

103BR **Chill-Vactor.** Units flash cool water, aqueous solutions, & other liquids to temperatures to 32° F. by partial evaporation at high vacuum. Croll-Reynolds Co., Inc.

IBC **Heat Exchangers.** Sectional fintube heat exchangers recommended for flexibility, no obsolescence, reduced fouling, easy cleaning, reduced stores, immediate availability. Brown Fintube Co.

OBC **Mixing Equipment.** Engineering service available to assure use of proper unit for required application. Mixing Equipment Co.

BULLETINS

1 **Process Equipment.** New catalog from Edw. Renneburg & Sons Co. introduces the DehydrO-Mat a new engineering concept in dryers. Illustrates component parts in addition to schematic drawing showing these parts. Features 3-way air pollution control by recovery of fines & dust, condenses objectionable water-soluble vapors, treats noxious insoluble fumes. Other equipment available is described and illustrated including reactors, rotary coolers, fans, & kilns.

2 **Moulded Fabric Parts.** Gatke Corp. has just issued a comprehensive catalog illustrating applications & describing unique properties of moulded fabric bearings, wear plates, & other parts. Shows bearings made for grease or oil lubricated, water lubricated, unlubricated, & acid resistant services. Journal sizes to 48 in. diam. & larger. Also moulded asbestos brake blocks, frictions, cones, other shapes.

3 **Pressurized Hydropads.** A low-cost surge arrestor for pipe line & instrument protection. Hydropads are used where sudden velocity changes in fluid pipe lines occur. Feature welded bellows of stainless steel filled with nitrogen. Bulletin includes basic data such as tables, formulae, & charts. Cook Electric Co.

4 **Valves.** Illustrations & descriptions on 12 basic control valve types used in marine & chemical process industries, power generating facilities, plus numerous liquid or gas pressure control applications are contained in bulletin from Atlas Valve Co. Also included are regulators & thermostats.

5 **pH Meter.** A pocket pH meter & revolutionary probe unit from Analytical Measurements, Inc. Self-contained in bakelite case. Size 3 x 5⅞ x 2¼ in. Meter scaled from 2 to 12. Gives readings 0 to 14.

6 **Pneumatic Transmitter.** Builders-Providence, Inc. announce technical bulletin on BalanCel pneumatic transmitter, model ATD. Designed for measuring flow, level, & differential pressures up to 35 lb./sq.in. in filtration & sewage plants. Also for low pressure industrial service.

7 **Process Equipment.** Project engineered dryers of many types, also continuous conveyor systems are subject of illustrated bulletin from Proctor & Schwartz, Inc. For use in chemical, pharmaceutical, food, & textile industries. Pertinent details, flow sheets, other data included.

8 **Transmission Systems.** From Automatic Control Co. Illustrated pamphlet on Autocon Telestep a positive automatic control system with remote transmission. For water, sewage & process plants. Reviews basic steps of five models, & discusses pressure, float & probe sensors used.

9 **Stainless Steel Data.** Micro Metallic Corp. loose leaf binder covers types, performance, & application data for stainless steel & other metals with controlled porosity. Outlines engineering services available from company in application of these materials.

10 **pH Control.** 4-page illustrated process data sheet published by Leeds & Northrup Co. Contains suggestions on measurement & control of pH of cooling tower water & describes suitable equipment. Includes conservation of make-up water, wood protection, scale prevention & minimization of slime.

11 **Heat Exchangers.** Precision fabricated heat exchangers for the process industries described & illustrated in bulletin from M. W. Kellogg Co. Sizes range from 6 in. diam. to 13 ft. shells with 8,000 tubes. Book features cross-sectional diagram of variety of units. Also illustrates heat treating facilities capable of handling vessels to 13 ft. in diam., 80 ft. long.

12 **Filter Fabrics.** An evaluation of various filter fabrics available in "Dust and Fume Topics," published by American Wheelbrator & Equipment Corp. Contains diagrams, discussion of seven primary properties, influence of cloth weave, other facets of the problem.

14 **Engineering Irons.** Bulletin from International Nickel Co., Inc. is a basic reference bulletin compiled especially for

design engineers. Contains tables, charts, photomicrographs showing how, by use of nickel alone or combining with other alloys, engineering properties of cast iron can be controlled to meet service requirements.

15 **Water Heater.** Said to provide dependable, efficient heating in many industrial applications, continuous pipe line water heater from Schutte and Koerting Co. Designed for direct connection to water or steam lines. Produces water temperatures rise to 100° F with water at 100 lb./sq.in./gauge & steam at 100 lb./sq.in./gauge. Well illustrated & detailed bulletin.

16 **Proportioning Pumps.** Positive displacement, reciprocating pumps for chemical injection, proportioning, pressure lubrication, & fluid transfer. Handle all aqueous solutions & liquid lubricants. Will inject or proportion additives into lines or vessels carrying to 30,000 lb./sq.in. pressure. Texsteam Corp.

17 **Polyester Glass.** Haveg Corp. material 7710 is glass reinforced polyester construction material developed for optimum chemical resistant & thermal properties. Technical bulletin lists table of chemical resistance, solutions for various uses in metal finishing.

18 **Mixers.** Catalog from Paul O. Abbé, Inc. includes various types of mixers for fast, efficient mixing of dry & paste products. Illustrated, details listed on each type. Additional catalog on ball & pebble mills.

19 **Valves.** Bar stock valves, control valves, digester valves, others plus methods of operation, special applications, installations & principle of operation are subject of bulletin from P-K Industries, Inc. Specialists in manufacture & sale of Paul Venturi ball valves.

20 **Hydro Filter.** Designed to automatically compensate for wide variations in volume & velocity of air flow. Maintains high separation efficiency. Dust laden air passes through filter bed of water droplets, film, bubbles, & mist. Folder gives dust test data other information. National Engineering Co.

21 **Oil Burners.** Thermal Research & Engineering Corp. folder on their high velocity oil burners. Contains complete information including operating principles, applications, dimensions, output data. For use in furnaces, ovens, dryers.

22 **Magnetic Separator.** Permanent, non-electric magnetic separators are considered in general catalog from Eriez Mfg. Co. Sections on installations; Magnalarm—sizes, models, & strength; pulleys; drums; grate magnets. Information on technical data, specifications, sizes.

23 **Tank Heaters.** Series BH & BW Cal-Fin bayonet tank heaters from Drayer-Hanson, Inc. 6-1/16 in. O.D. over fins, provides 9 sq.ft. heating surface/ft. of length. Fins 25/32 in. high x 0.35 in. thick are wound in continuous helix with flange welded to seamless steel tubes. Folder.

24 **Liquid Cooler.** A packaged liquid cooler from Doyle & Roth Mfg. Co. includes complete refrigeration cycle, compressor, motor, & starter, refrigerant controls, other parts ready for quick installation & immediate operation. Sizes range from 5 to 100 tons of refrigeration.

25 **Centrifugal Pumps.** Frame mounted self-priming centrifugal pumps. Capacities to 550 gal./min., heads to 140 ft. sizes 1½ to 4 in. available from Worthington Corp. Folder shows schematic drawings, specifications, applications.

26 **Cooling Tower Performance.** Booklet from Marley Co., "Test Your Tower" devoted to simple method which insures good performance of an industrial cooling tower. Sections on test procedure & theoretical considerations.

27 **Centrifugal Pumps.** Bulletin on vulcanized-rubber-lined, stainless steel, & cast steel centrifugal pumps. Illustrated, cutaway views included. Give good corrosion resistance, are easily adjusted, easy access to stuffing box, one-piece rotating element are among features. Industrial Filter & Pump Co.

28 **Impregnation of Castings.** Brochure illustrating modern casting impregnation available from American Metaseal Mfg. Co. Method said to prevent casting leaks, corrosion, prolongs part life, prevents finish failures, permits no bacterial or fungus growth. Covers both cast & metal powder parts.

29 **Process Equipment.** Binder insert catalog covering specialized equipment for the process & chemical industries issued by Patterson-Kelley Co., Inc. Illustrations & specifications on many sizes & adaptations of three basic types of blenders. Production sizes on ribbon, double cone, patented twin shell models, plus 1 pt. to 8 qt. laboratory sizes for twin shell. Twenty cooling & heat exchange units.

30 **Plug Valves.** Lubricated plug valves for service with gasoline, oil, water, air, gas, acids, caustic solutions, & other chemicals. Now equipped with Teflon gaskets. Detailed descriptions, special features, schematic diagrams, dimensions, other data included in recent catalog. ACF Industries, Inc.

31 **Regulating Devices.** Automatic regulators for every purpose are described & illustrated in folder from Atlas Valve Co. Specially designed equipment also available. Line includes reducing, regulating, control valves.

32 **Manufacturing Activities.** A 50-page brochure from Blaw-Knox Co. covers illustrated material on all major departmental operations in eleven divisions of company. Emphasis is on products & services & their industrial applications.

33 **Pressure Vessel Codes.** Supplement to "An Over-All Comparison Between Two Pressure Vessel Codes," by Walter Samans featured in Alco Products Review published by American Locomotive Co. Also carries feature article on new oil refinery & other material of interest.

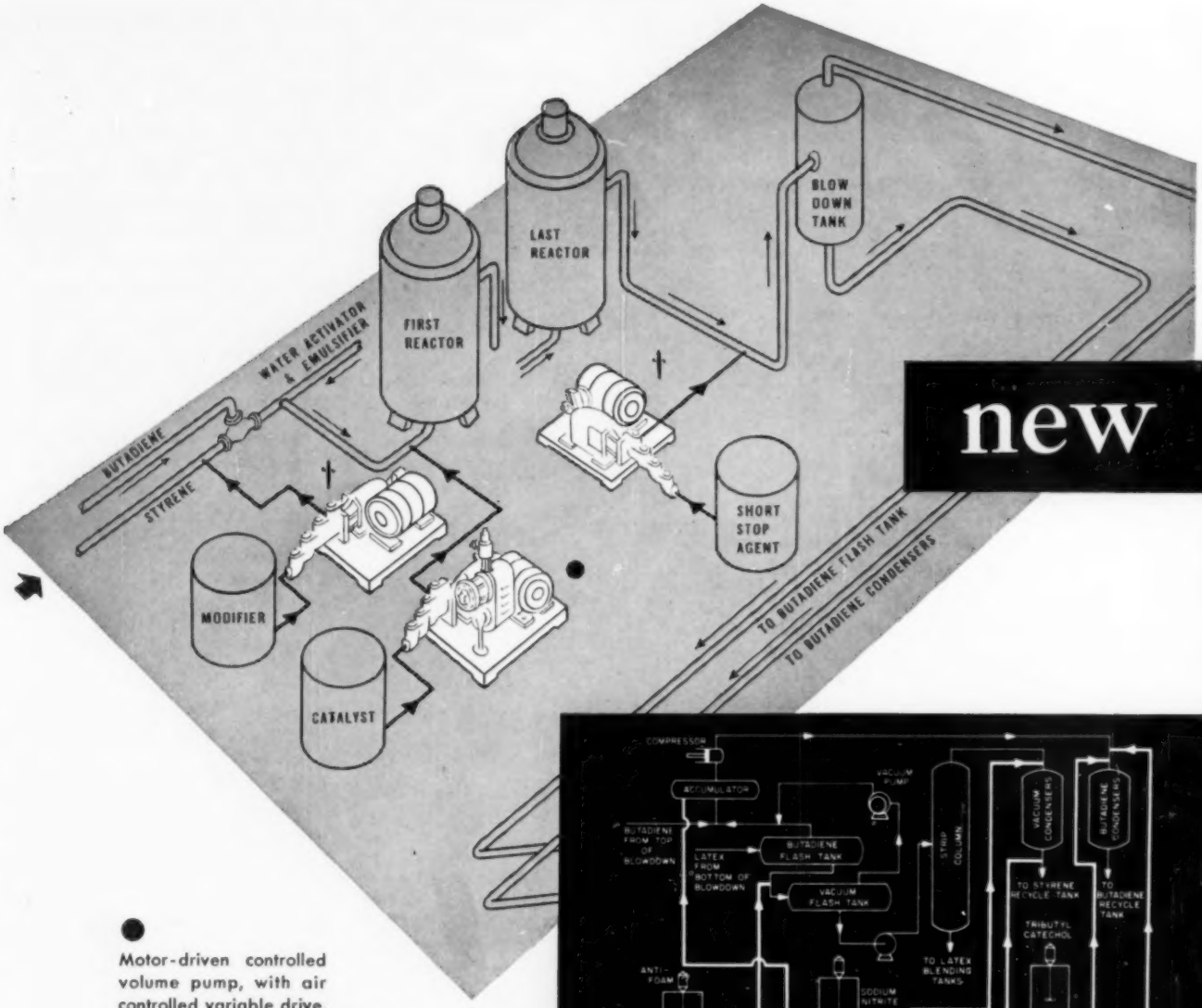
34 **Lime Slakers.** Bulletin contains brief description of continuous milk-of-lime process. Shows general arrangement & dimensions of various size slaking systems of Hardinge Co., Inc. including the hydro-classifier in series with the lime slaker. Also other equipment in line.

35 **Mixed & Axial Flow Pumps.** Flyer from Ingersoll-Rand Co. on their horizontal mixed & axial flow pumps. Incorporates dimensions, materials table, sectional drawings with details. For process industry & paper mill applications. Sizes 10 to 24 in. with pressures to 25 lb./sq.in., capacities to 16,000 gal./min.

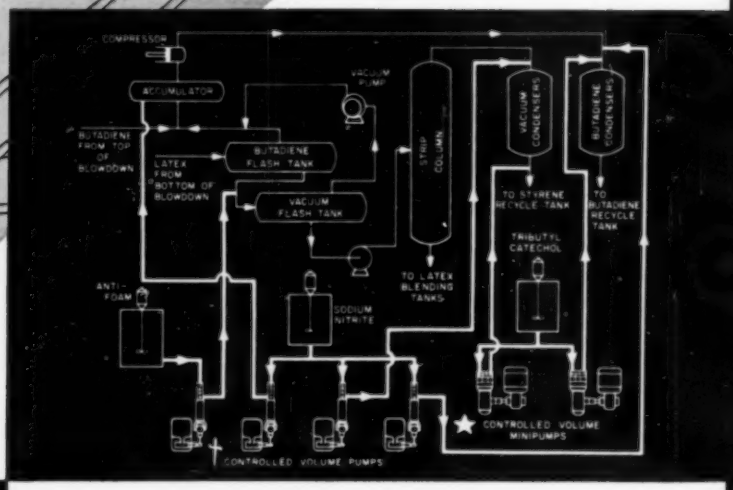
36 **Electronic Systems.** Custom engineering of electronic instrumentation to specific industrial, scientific, & military needs covered in brochure from Consolidated Engineering Corp. Incorporates case histories of typical systems, applications, & method of planning for solution of problems.

37 **Strain Gauge Load Cells.** Instrumentation data sheet from Minneapolis-Honeywell Regulator Co. describes use

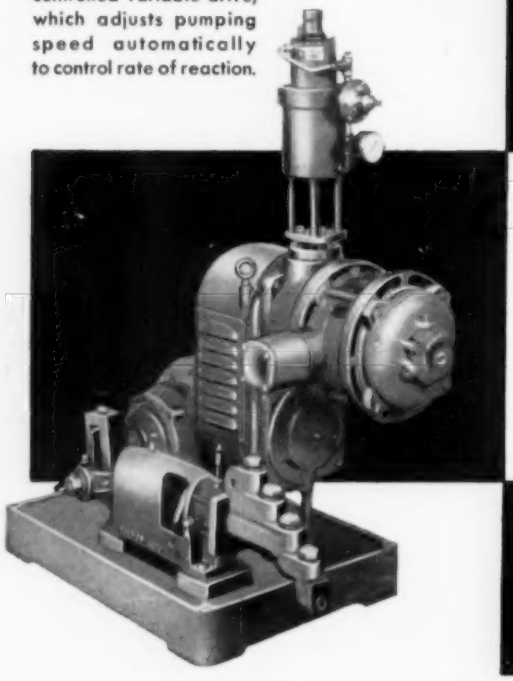
(Continued on page 54)



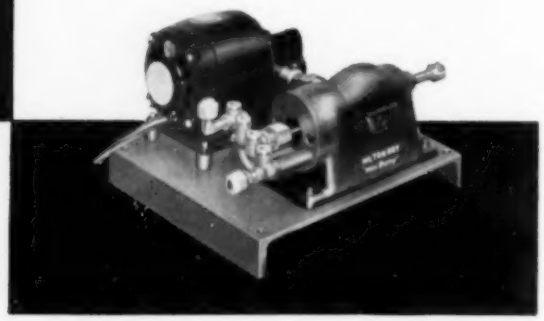
new



● Motor-driven controlled volume pump, with air controlled variable drive, which adjusts pumping speed automatically to control rate of reaction.



★ Two "minipumps" on recovery system accurately control addition of inhibitors to stabilize monomers following recovery.



flow-control approach

guards product quality in continuous polymerization

Controlled volume pumps are flow control instruments

PRECISE flow control—accurate metering of catalysts, inhibitors, defoamers, and other additives—largely determines product quality in continuous polymerization of rubber. Milton Roy *controlled volume pumps* have taken over this flow control job with excellent results.—More precise control. No over- or under-treatment. Better product quality. Significant savings on costly additives.

Reason: controlled volume pumps are actually flow control instruments . . . particularly valuable for low capacity flows. Reciprocating, positive displacement type pumps, they precisely meter process additives to an accuracy of within 1%! Exclusive Milton Roy ball-type *step-valve* design assures accuracy with any viscosity liquid or slurry. Pumps are available in capacities up to 1350 gallons per hour . . . pressures up to 50,000 pounds per square inch . . . with manual or automatic speed and stroke adjustment.

Note diagram, left. Where can controlled volume pumps be profitably applied in your own process? Milton Roy offers you long experience in handling low capacity flow control problems . . . in engineering complete chemical feed and automatic control systems. Write for technical information. Or, send your problem to the Milton Roy Company, *Manufacturing Engineers*, 1300 East Mermaid Lane, Philadelphia 18, Pennsylvania.

Engineering representatives in the United States, Canada, Mexico, Europe, Asia, South America, and Africa.

milton Roy
CHEMICAL FEED SYSTEMS

†

Standard motor-driven controlled volume pumps . . . three in Butadiene inhibiting service (preventing "popcorn" polymers) . . . other three meter accurate quantities of modifier, anti-foam and short-stop agents to process stream.

BULLETINS

(Continued from page 51)

of Baldwin SR-4 load cells in conjunction with other instruments manufactured by them. Design considerations, & instrument selection information included.

38 **Welding Methods.** Folder of interest to those engaged in welded stainless tubular products available from Babcock & Wilcox Co. Outlines welding characteristics of austenitic & ferritic grades & discusses proper joint design. Also describes various welding methods, gives tables of recommended arc welding procedures.

39 **Pressure Filters.** Gravity & pressure filters plus equipment to furnish complete filter plants are described & illustrated in brochure from Permutit Co. Filters now in use for removal of suspended solids such as dirt, turbidity, iron, oil, color. Of interest to engineers concerned with water problems.

40 **Filteraids.** Accomplishing industrial filtration with Dicalite filteraids is the subject of a well illustrated bulletin from Dicalite Div., Great Lakes Carbon Corp. Contains origin of materials, description of various grades available, plus information on how to use them for greatest efficiency.

EQUIPMENT

45 **Centrifugal Pumps.** Two sizes of Camac cast steel centrifugal pumps available from Carl Buck & Associates, with heads 10 to 150 ft. & flows of 10 to 200 gal./min. Seal is either Camac special acid or Teflon & may be water-cooled or not. Designed for rough chemical service. Units & parts available from stock. Performance curves & prints from manufacturer.

46 **Butterfly Valves.** Extended by Builders-Providence, Inc. line of butterfly valves for general service. Combination of utilitarian design & rugged construction result in positive, trouble-free performance. Meet American Water Works Assoc. tentative standard specifications. Accessories include manual, electric, hydraulic, & pneumatic operators.

47 **Temperature Sensing Device.** An instrument which accurately measures process temperatures & pneumatically transmits information to central recording or controlling station announced by Foxboro Co. Device is non-indicating, force balance type, calibrated accuracy of ½% of temperature span & compensated for ambient temperature & barometric pressure variations. Spans range from 50 to 400° F, for utilization between limits of —100 & +1,000° F.

48 **Immersion Heater.** Named ThermX an immersion heater constructed with chemically pure fused quartz shell chemically inert from practically all solvents except hydrofluoric acid & concentrated hot caustic solutions. Said to have good thermal shock resistance & heat conductivity. Available in lengths from 10 to 34 ft.; 500 to 6,000 w.; 115 to 230 v. Thermex Co.

49 **Relief Valve.** A pop-off relief valve said to be of simple, sturdy, trouble-free construction which seals tight with no leakage below release pressure from James-Pond-Clark. Reseats dead tight within 10% of valve. Sealing provided by special member. For applications where pressures from 1 to 125 lb./sq.in. & maximum flow & minimum pressure drop are required.

50 **Industrial Mixer.** A mixer employing a new design principle from Gabb Special Products Div., E. Horton & Son Co. For use in mixing, homogenizing or dispersing, & available with 1½ to 5 hp. motors. Mixing head creates double shearing action. Easy to clean, creates no vortex, operating torque or clogging. Minimum of aeration.

51 **Rotary Air Lock.** Called Pulvalve & said to have many exclusive features which make it a superior rotary air lock or valve, more effective in its sealing qualities than others by Pulva Corp. Wiper blades of various materials including Teflon & nylon.

52 **Mist Collector.** Elimination of oil mist & smoke at its source. Dollinger Corp. illustrated folder. Mist collector designed for mounting on or near high speed grinding & cutting machines. Three new models include exclusive advantages.

53 **Vacuum Tube Gauge.** Hastings Instrument Co. announces newly designed vacuum gauge tube. Retains permanent calibration yet withstands intense vibration, shock & temperature change. For use with other units in their line. Short sensing elements, butt-welded noble metal thermocouples. Respond in one-half second. Employ ⅛ in. I.P.S. male thread.

54 **Swivel Joints.** Type S swivel joints in sizes ½ to 2 in. in four styles, for high pressures & for high temperatures, Stock sizes have malleable iron casing & steel ball. For use in providing movement in metal piping connected to movable machinery. Barco Mfg. Co.

55 **Corrosion-Resistant Valves.** Complete new line of alloy gate, blobe, & angle valves announced by Crane Co. Exclusive split-wedge disc design in gate valves, improved disc-stem connection in globe & angle valves. Teflon packing in all valves. Chattering of disc eliminated & seat wear reduced.

56 **Heat Exchanger.** Designed for continuous velocity & rapid heating operations, stainless steel heat exchanger from Oscar Krenz, Inc. Especially applicable for handling heat sensitive material. Operates as individual unit. Three available accessories—temperature controller of discharged products; vacuum system protects against burning; & a recirculation system which provides continuous high velocity product flow.

57 **Recorder-Controller.** Self balance recorder-controller said to be sensitive & accurate & developed for use in wide range of industrial process operations, announced by Robertshaw-Fulton Controls Co. Called Series 42 radio frequency capacitance bridge, it was designed for measurement & control of levels of liquids, granular solids, other materials. Electrical or pneumatic control forms available. Accurate to ¼ of 1%.

58 **Gas Sampling Unit.** Added to Arnold O. Beckman, Inc. line of instruments, portable gas sampling unit. Provides means for bringing sample gas stream to analyzer for measurement. Easily operated. Pump works on 115 v. a.c.

59 **Bayonet Heat Exchanger.** Improved design of this heat exchanger eliminates heavy flanges, minimizes installation area required. Condensate removed by small internal steel pipe riser & joint between header & Karbate tube is reinforced with fiberglass. May be used for heating or cooling, or alternately for both. Carl Buck & Associates.

78 **Heat Exchangers.** Semi-standard heat exchangers now

This prevulcanized sheet lining shows maximum abrasion

60 Boiler. Radical new design in boilers presented by Brown Fintube Co. Illustrated bulletin cutaway section shows internally finned tubes which produce fireside to waterside surface ratio of 3:1 as compared to 1 to 1.1 for plain tubes. Increased surface area for pickup of heat & transfer to water. Sizes 30, 60, & 100 h.p.

61 Jar Rolling Mill. Paul O. Abbé, Inc. announce a jar rolling mill with containers 2 in. to 13 in. diam. Diameter range made possible by movable idler roll. Roll may be lifted out of notches to secure correct space for containers used. No lubrication required for sealed ball bearings used on both fixed & movable rollers. Removable tray, support castings are iron, entire unit assembled on steel base plate.

62 Dust Filter. Folder from Ducon Co. illustrated with diagrams, photographs, cutaway views, of new fiber dust filter type FD. Compact unit, easily operated suitable for variety of industrial dust problems, such as creation or freeing of lint or other fibrous material. Eliminates repeated cleaning & rehandling of fabrics, improves general efficiency.

63 Ultrasonic Equipment. Useful in fields of quality control, manufacturing, food processing, & industrial & scientific research seven ultrasonic units from Curtiss-Wright Corp. Three designed for manufacturing & experimental work, two for quality control, two for food process industry. For manufacturing the Diatron drill, a parts washing unit and ultrasonic generator for various types of laboratory work.

64 Air Operated Valves. Completely new, a line of air operated Saunders patent type valve, sizes ½ to 4 in., with flanged & screwed in spring type, & springless, with operating air to both open & close. For use in the chemical, food, paper, & water treating industries. Choice of body materials, also linings. Bulletin includes complete data for sizing, dimensions, specifications in easily usable form. Uniflow Valve Corp.

65 Regulating Valve. A pressure reducing & regulating valve said to have extremely low pressure drop & lockup, added to line of A. W. Cash Co. A self-contained, single seat valve, operates on range of 300 lb./sq.in. inlet pressure & 3 to 250 lb./sq.in. delivered pressure. Minimum size & weight with high sensitivity. Interior readily accessible for servicing without removal from pipeline. Available in variety of materials.

66 Solenoid Valve. An improved, compact, straight-through-flow, high pressure solenoid valve said to conserve space & require low power consumption, from Specialty Products Co., Inc. Unit is 2⅝ in. long, 1⅜ in. diam., weighs 5 ounces. Available in 6, 12, 24 v.d.c. & 110 to 120 v.a.c., waterproof, for use in ambient temperatures from —65° to +350° F. Orifice range 1/16 to 9/64 in. diam.; inlet connections ¼ in. N.P.T. & outlet ⅛ in. N.P.T.

67 Fine-Weld Seam. Perfection of a welded side seam of unusual strength & uniformity developed by Bemis Bro. Bag Co. Method produces thin, beaded seam said to be stronger than the polyethylene film itself. Process permits manufacture of seamless bottom polyethylene bags that leave full front & back surfaces for brand printing. No interruption by center seam.

68 Humidifier. For use in smaller rooms & enclosures new humidifier from Spraying Systems Co. Full-range humidity adjustment for rooms to 12,00 cu.ft. in size. At recommended pressure of 32 lb./sq.in. unit atomizes water at rate of 2 gal./hr. using 2.9 cu.ft. of air a minute.

69 Flow Valve. Constant flow valves which maintain rate of flow of fuel oil or other non-abrasive field within 1% up to 200 to 700 gal./hr. developed by Askania Regulator Co. Flow level accurately maintained if fluid viscosity & temperature remain constant & pressure differential across valve is 40 lb./sq.in. or higher for maximum flow.

70 Change Can Mixer. For rapid mixing & dispersion of inks, paints, chemicals, other materials, with viscosity to 40,000 centipoises a change can mixer developed by Stevenson Co. 5 to 15 hp. sizes to handle vessels to 42 in. diam. Mixer has 15 in. diam. shrouded turbine. A variable speed unit, it operates at 320 to 640 rev./min. May be used sitting on floor, on pallets or small dollies.

71 Back Pressure Valves. Loose leaf binder inserts from A. W. Cash Valve Mfg Corp. on newest addition to line, type FR back pressure relief valves. Available in pipe sizes ½ to 2 in. in iron, bronze, stainless steel or Monel bodies, suitable for pressures to 400 lb./sq. in. Patented floating ring principle is feature of valve. Removes substantial friction caused by drag of piston & cylinder usually found in valves.

72 Data Accumulation & Reduction. Called Vic-Dar unit is essentially an electronic brain for testing variables including speed, position, motion, etc., & translating them into digitized values for use in analysis. Victor Adding Machine Co.

73 Liquid Meter Register. New with Neptune Meter Co. liquid meter register which automatically stamps ticket with quantity of liquid ingredients delivered to batch or process. Provides closer quality control & inventory because of permanent printed record. Identifies operator & batch by printing letters & serial numbers. Sizes 1 to 4 in., rates of flow 5 gal./min. min. to 50 gal./min. max.

74 Portable Laboratory Dryer. Completely self-contained portable dryer available from C. G. Sargent's Sons Corp. Any phase of drying cycle may be varied for testing without disturbing others. Pressure of air source 40 & 150 lb. Designed for steam or electrical heating of air stream. Steam to 300° F., electrical heating to 500° F. Recommended supply of air pressure, 20 lb. Wet or dry bulb controls. Folder.

75 Multi-Cyclone System. Mechanical dust collector called Paraclone available from Aerodyne Development Corp. Differs from conventional type by use of secondary circuit keeping discharge from small cyclones under negative pressure. Efficient for collection of particles in range 0 to 15 microns. Adaptable to high- or low-temperature gases.

76 Valves. Higher temperature service now available from Grinnell-Saunders valves using chemically inert Teflon diaphraghms bearing designations of R-1 & R-2. Cover range of —40° F. to +375° F. Parts are built with larger, more rugged floating tube nut to permit use in vacuum service. Grinnell Company, Inc.

77 Emulsifying Machine. An ultrasonic device producing permanent emulsions of two or more liquids otherwise difficult or impossible of mixing together. Action results from intense cavitation forces of focused ultrasonic waves producing fine division of one liquid into another. McKenna Laboratories.

78 **Heat Exchangers.** Semi-standard heat exchangers now available from Downingtown Iron Works. Units are designed to meet wide variety of heat transfer problems. Prompt delivery assured even on units having optional design features specified. Constructed of tube sheets 7/8 in. & up; bonnets & channels 3/16 in. Stainless steel nozzles schedule 40 stub ends having ASA lap-joint flanges.

79 **Continuous Mixers.** Continuous-type mixing & plugging machines engineered to handle material from dust to 1½ in., either dry state or slurry, available from Colonial Iron Works. Standard sizes engineered with production capacities as required. For use in chemical process industries. Said to be advantageous where greater production & increased batch sizes are required.

CHEMICALS

80 **Textile Chemicals, Oils, Waxes.** The story of the history of L. Sonneborn Sons, Inc. manufacturers of detergents, lubricants, & other products is illustrated and described in their new brochure.

81 **Phosphorus Tribromide.** Now available in commercial quantities from Michigan Chemical Corp. is phosphorous tribromide having a specific gravity of 2.88 & a high boiling point. Important use is ability to convert alcohols to corresponding bromides or acids to acid bromides. Prepared for synthetic compounding; specifications include maximum boiling range of 2° C.

82 **1,2-dichloroethylene.** Physical & chemical properties & various reactions of 1,2-dichloroethylene are covered in new technical data report from Monsanto Chemical Co. Uses include refrigerating liquid, solvent for fats & oils, extraction of caffeine from coffee. Also covers toxicity & storage. Source bibliography included.

83 **Synthetic Organic Chemicals.** The 1955 edition of the booklet "Physical Properties of Synthetic Organic Chemicals," now available from Carbide and Carbon Chemicals Co. Serves as a handy guide to chemists, engineers, purchasing agents, & laboratory workers. Chemicals arranged in family groups with condensed application data. Physical properties in tabular form.

84 **Phenolic Cement.** Haveg Corp. No. 4310 cement is carbon filled phenolic cement developed for use in brick lining of tanks, laying of brick & tile floors, plus similar uses in chemical process field. Technical bulletin includes description of material, its physical properties, heat & chemical resistances.

85 **Nonionic.** Stephan Chemical Co. HDA-7 is a nonionic of the fatty acid alkylolaminde type for use in heavy duty hard surface cleaners. Addition of product said to hold in solution a phosphate content to 11% for more cleaning power.

86 **Solvents.** Two new glycol ether solvents & intermediates Dowanol 8 & Dowanol 17, available in tank car quantities, announced by Dow Chemical Co. Dowanol 8 (ethylene glycol ethyl ether) a resin solvent is used in lacquer, dye & ink formulations. Dowanol 17 (diethylene glycol ethyl ether) a brake fluid solvent useful in lacquer. Its fiber penetration improves effectiveness in textile manufacture. Also used as intermediate in phthalic plasticizers. Dow Chemical Co.

87 **Neoprene Sheet Lining.** Addition of Neoprene No. 750 sheet lining to line of Carboline Co. products announced. This prevulcanized sheet lining shows maximum abrasion resistance, protection against acid & alkali corrosion. Supplied in rolls 32 to 34 in. wide & various lengths. Thicknesses are 1/16, 1/8, & 3/16 in. according to service requirements.

88 **Alkyl Halide Bulletin.** Aceto Chemical Co., Inc. has just issued new technical bulletin on alkyl halides. Describes alkyl chlorides of various chain lengths, as well as alkyd bromides.

89 **Rubber Compounding Material.** From Barrett Div., Allied Chemical & Dye Corp. announcement of new hydrocarbon rubber compounding material for use in products of the black, elastomeric type. Designed to replace other hydrocarbons unavailable because of raw material shortages. For use in processing materials offering resistance to petroleum oils & solvents requiring adherence to minimal dimensional variations.

90 **Liquid Primer.** Developed in the laboratories of Pennsylvania Salt Mfg. Co. a corrosion resistant liquid primer for new or corroded steel surfaces. May be applied by brush, roller, or directly from can. Forms tight, adherent bond to surface & provides excellent adhesion for following coats of Pennsalt NeoCoat or Thickcoat. Also effective in acidic & organic atmospheres.

91 **Vaccenic Acid.** Jasonols Chemical Corp. announces production of vaccenic acid, trans-11-oleic acid. Has an m.p. of 30 to 35° C, iodine value of 75 to 80, neutralization equivalent of 280. High melting point will make it more useful in cosmetic, food & industrial formulations. Because of its trans configuration it is more resistant to oxidative rancidity than oleic acid or any of its cis isomers.

92 **Metal Protection & Paint Bonding Chemicals.** Folder from American Chemical Paint Co. covers concise descriptions of chemicals for metal protection & paint bonding including alodine, lithoform, & granodine.

93 **Silica Gel.** Reactivation of silica gel & regeneration of Protek-Sorb 121 are subject of product data sheet from Davison Chemical Co. Covers desirable equipment & procedure.

94 **Silicones.** Dow Corning Corp. 1955 reference guide on their silicone products lists 23 new products in addition to 100-odd previously mentioned. Contains tables, graphs, & photos. Pertinent details included.

95 **Maintenance Coating.** Hypalon a maintenance coating based on DuPont's Hypalon chloro-sulfonated polyethylene from Atlas Mineral Products Co. Material is flexible, self-curing, easily applied in heavy coats, has excellent adhesion qualities.

96 **Data Book.** Listed in data book from Zonolite Co. over forty industrial applications of vermiculite, plus revised information on physical & chemical properties. Also discusses uses in terms of absorption, & other characteristics.

97 **2,4,7-Trinitrofluorenone.** Complete literature review of this material given in recent publication from Dajac Laboratories. Reagent has been used to form stable, brightly-colored, sharp-melting complexes with polynuclear hydrocarbons & derivatives.

98 **Textured Finishes.** Brochure from Midland Chemical Corp. describes custom chemicals prepared for industrial finishes of large variety of products. Announces two new chemicals based on Dextran.

what is your **PULVERIZING** problem?

we'll test grind a sample for you

with the

SCHUTZ-O'NEILL

Superfine

PULVERIZER

What is your milling problem—uniformity? fineness? Do you need increased output at a lower cost? Without obligation to you, we'll grind a sample of your material in our pilot plant, using a production model Schutz-O'Neill "Superfine" Pulverizer. We'll return your processed product with our Engineering Test Report giving exact data and including recommended Schutz-O'Neill equipment, methods and mill plans for your job.

This will give you full information on the versatility, particle size range and capacity of Schutz-O'Neill "Superfine" Pulverizers. Backed by more than 60 years of continuous manufacturing and field experience.

SCHUTZ-O'NEILL PILOT PLANT uses a standard production model 16" Superfine Pulverizer. Mill components on wall at left in photo provide up to 100 different pulverizing setups, with a range from 40 mesh to 5 microns.

Below are two typical pulverizing problems that were solved by SCHUTZ-O'NEILL

NO. 1 PULVERIZING CERAMIC MOLDING MATERIALS

THE PROBLEM: To develop ceramic materials for precision molding of high temperature, high fidelity alloy castings for jet aircraft engines. Castings of molybdenum, columbium, and other rare metals were to be made. By producing precise castings, less machining is required and more rare metal saved. The particle size for best results (determined by university consultants) fell within the 60 to 200 mesh range.

THE TESTS: The Schutz-O'Neill pilot plant processed 200 pounds of the feed material, in a series of tests with the university ceramic consultants and the contracting firm present.

THE SOLUTION: Schutz-O'Neill designed a system that is now producing 1,000 to 1,200 pounds per hour of ceramic material 85 to 90 percent within the required 60 to 200 mesh range.

NO. 2 PIGMENTS UNDER 25 MICRONS FOR COLORING PLASTICS

THE PROBLEM: A leading chemical firm producing a variety of resins and plastics wanted to reduce and intimately blend pigments for coloring molded plastic forms. The manufacturer found that particles larger than 25 microns produced streaks in the finished molding. In addition, tints prepared from more than one color necessitated absolute dispersion and optimum blending to insure proper shading and depth.

THE TESTS: Pilot plant test runs were conducted at Schutz-O'Neill. The resulting product was analyzed in the manufacturer's lab. In their report to Schutz-O'Neill, the firm stated, "In all our tests your grinder was equal to or better than the others from the standpoint of fineness of grind and absence of pigment specks in our product".

THE SOLUTION: The chemical firm is being supplied with a 22" Schutz-O'Neill stainless steel Pulverizer.

Write Us:

Tell us the stock you want to pulverize, fineness, capacity desired; we'll send shipping instructions. Or, write for literature desired on Schutz-O'Neill Pulverizers, Granulators, Roller Mills, Sifters, Cyclone Collectors, Hammer Mills.

ESTABLISHED 1893

SCHUTZ-O'NEILL COMPANY

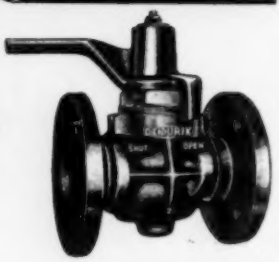
FULVERIZERS • GRANULATORS • ROLLER MILLS • CYCLONES • SIFTERS • HAMMER MILLS

339 PORTLAND AVENUE • MINNEAPOLIS 15, MINNESOTA

A Full Range of Metals in DeZURIK

IRON or STEEL
BRONZE
ACID RESISTING BRONZE
NI RESIST
STAINLESS STEEL
MONEL
HASTELLOY
NICKEL
ALUMINUM
OTHER ALLOYS

VALVES



There's a DeZurik Valve to handle almost anything piped—from acetic acid thru ethylene glycol and potassium dichromate to zinc sulphate.

The wide range of applications in the chemical processing industry has proved the unique qualifications of DeZurik Easy-Operating, Non-Lubricated Plug Valves. Their eccentric-shaped resilient-faced plugs provide the tightest shut-off for the longest time!

In addition to the metals listed above, DeZurik Valves are also available in rubber-lined models. These versatile valves come in a full range of models, too . . . with manual, remote or automatic operation.

PLUGS

Plug facings are supplied in several materials: Hycar rubber in three compounds, Neoprene in three compounds and Teflon. For high temperature services, plugs can be furnished with metal faces.

Write for details and recommendations

DEZURIK SHOWER CO.
SARTELL, MINN.

CANDIDATES FOR MEMBERSHIP IN A. I. Ch. E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on admissions.

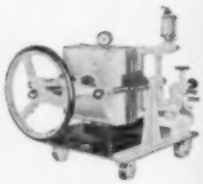
These names are listed in accordance with Article III, Section 8, of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Members will receive careful consideration if received before March 15, 1955, at the office of the Secretary, A.I.Ch.E., 25 West 45th Street, New York 36, N. Y.

Member

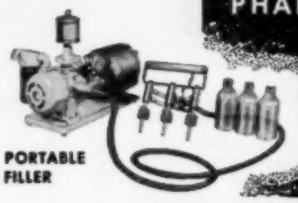
Agarwal, Jagdish C., *Verona, Pa.*
Albert, R. E., *Newark, Del.*
Alexander, Earl L., *Wilmington, Del.*
Allison, Robert J., *Coraopolis, Pa.*
Becker, Kenneth W., *Chicago, Ill.*
Cronan, Calvin S., *New York, N. Y.*
Dohan, Jerome, *Baltimore, Md.*
DuPont, George V., *Shaker Heights, Ohio*
Haddad, George J., *Pittsburgh, Pa.*
Heiss, John F., *So. Charleston, W. Va.*
Henke, Alfred M., *Springdale, Pa.*
Henry, Russell W., *Northwoods, Mo.*
Hill, Donald P., *Woodbury, N. J.*
Hocott, Claude R., *Houston, Tex.*
Holeman, John W., *Baton Rouge, La.*
Hutson, Tom, Jr., *Phillips, Tex.*
Kiddoo, Richard C., *Towson, Md.*
Livesay, P. Craig, *Sugar Creek, Mo.*
Lounsbury, Charles W., *Westfield, N. J.*
Malone, James C., *St. Albans, W. Va.*
Ott, Henry C., *Washington, D. C.*
Pickett, M. E., Jr., *Monroe, La.*

(*Continued on page 62*)



EFS-B FILTER

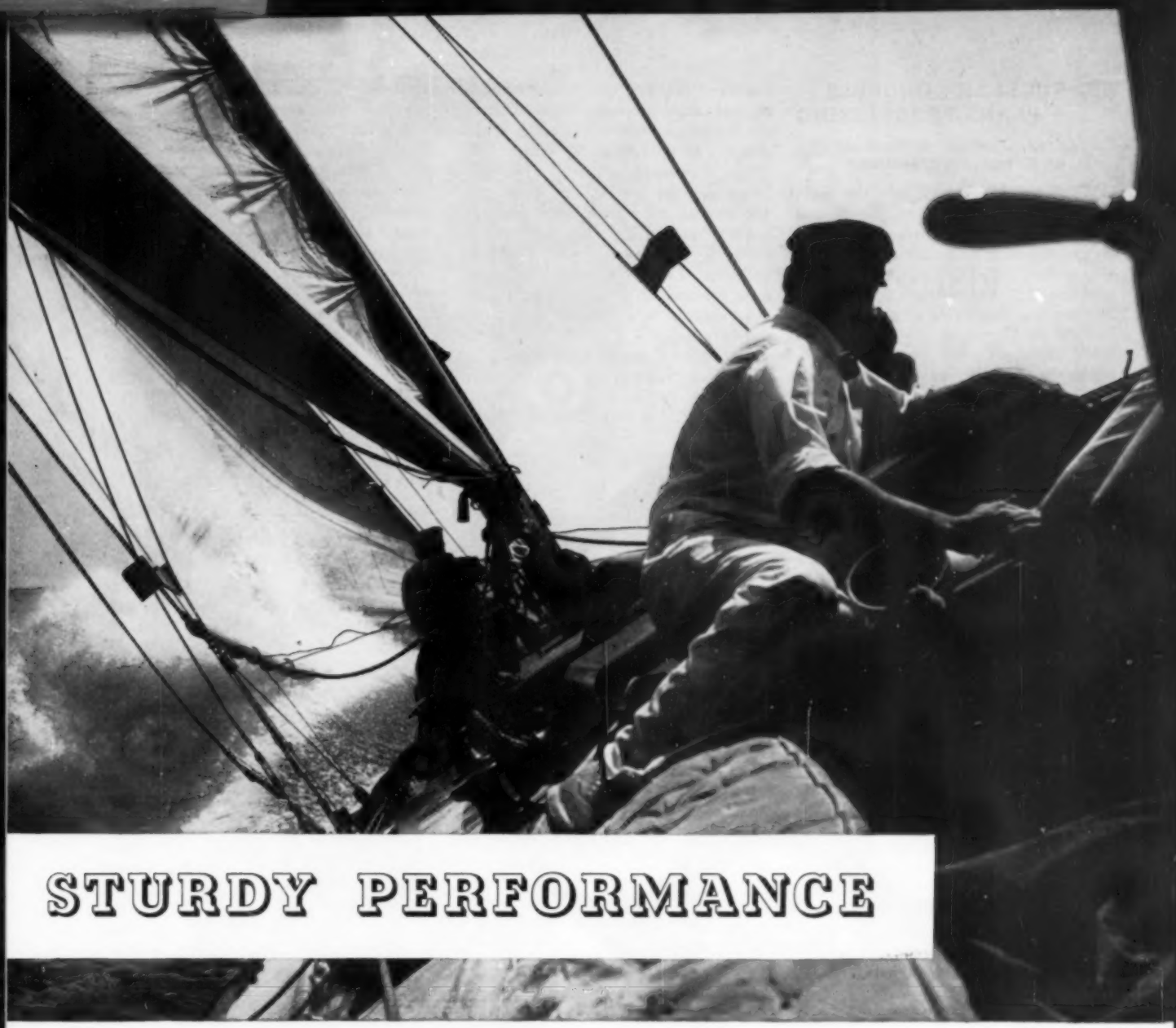
For FILTERING and FILLING
small plant or batch lots of
PHARMACEUTICALS, COSMETICS, CHEMICALS, FOODS, DRUGS, SOAPS, ETC.



PORTABLE FILLER

Two Ertel units that make small production efficient. They have all the desirable features of Ertel high production equipment: EFS-B FILTER has single hand wheel for simple trouble-free operation, bronze or stainless circulatory system, accommodates accepted Ertel Asbestos Filter Sheets. PORTABLE FILLER has automatic overflow system, non-drip spouts, bottle size flexibility up to gallons. And, both units can be easily moved from place to place. Write for detailed information on this important equipment . . . it belongs in your plant.

ERTEL ENGINEERING CORPORATION
KINGSTON 4, NEW YORK
Branch Office & Showroom Located in New York City
COMPLETE LINE OF *Liquid Handling Equipment*
THOMAS REGISTER
ERTEL



STURDY PERFORMANCE

The sturdy performance of GLC ANODES in electrolytic cell operations is the reason why major chlor-alkali producers rely upon them with increasing frequency.

ELECTRODE GLC DIVISION

Great Lakes Carbon Corporation

GRAPHITE ANODES, ELECTRODES, MOLDS and SPECIALTIES

ADMINISTRATIVE OFFICE: 18 East 48th Street, New York 17, N.Y.
PLANTS: Niagara Falls, N.Y., Morganton, N.C.
OTHER OFFICES: Niagara Falls, N.Y., Oak Park, Ill., Pittsburgh, Pa.
SALES AGENTS IN OTHER COUNTRIES: Great Northern Carbon & Chemical Co., Ltd., Montreal, Canada
Overseas Carbon & Coke Company, Inc., Geneva, Switzerland; Great Eastern Carbon & Chemical Co., Inc., Chiyoda-Ku, Tokyo, Japan

EJC NUCLEAR CONGRESS PLANS PROGRESSING

A.I.Ch.E. "ATOMIC EXPOSITION" TO BE HELD SIMULTANEOUSLY

What may very well be "the most comprehensive program of papers and discussions looking toward industrial uses of the atom to benefit all mankind" —to quote J. R. Dunning, chairman of the General Committee on Nuclear Engineering and Science of EJC—will be held in Cleveland, Ohio, December 12-17, 1955. Twelve professional societies have united to co-sponsor this Nuclear Congress, which represents the biggest single project yet undertaken by the combined engineering and scientific societies of the nation.

The Atomic Exposition is expected to bring together for the first time under one roof all the major developments in industry and science having to do directly to atomic energy. In addition, industrial exhibitors of related equipment for nuclear power and other plants are expected to exhibit in considerable numbers.

Exhibition site will be Cleveland Municipal Auditorium. 225,000 square feet of space has been made available, together with auditorium facilities for concurrent meetings of the Congress. These include the 10,000-seat Arena, the 3,000-seat Music Hall and eight other rooms with capacities ranging from 125 to 1,300. All major Cleveland hotels have set aside a total of 3,400 rooms for the week of the Congress and Exposition, and are also making available their meeting rooms.

Management for the Exposition, under sponsorship of A.I.Ch.E., will be Atomic Exposition, 931 Book Building, Detroit 26, Mich. The Exposition director will be Athel F. Denham, who may be contacted at the Detroit address for further information.

OAK RIDGE REACTOR SCHOOL ACCEPTING APPLICATIONS

Applications for enrollment in the 50-week session of the Oak Ridge School of Reactor Technology beginning in September, are now being accepted. Enrollments close March 14. The school is a part of Oak Ridge National Laboratory, which is operated for the AEC by Union Carbide & Carbon Corporation.

Industrial organizations may enroll a limited number of their technical personnel in the ORSORT. The AEC, aware of the growing need for competent nuclear reactor engineers, has made this participation possible to encourage nuclear progress in industry. Tuition is $2,500 for students from industrial firms other than AEC operating contractors.

Students who are accepted will have the opportunity of participating in a curriculum of an advanced type, including courses covering classified details of reactor technology. A variety of full-scale working reactors and other large units of equipment are available for use with ORSORT courses.

A. M. Weinberg, Director of Research, Oak Ridge National Laboratory, addressing students of ORSORT.

(*Continued on page 68*)

CONSECO SERVICE—

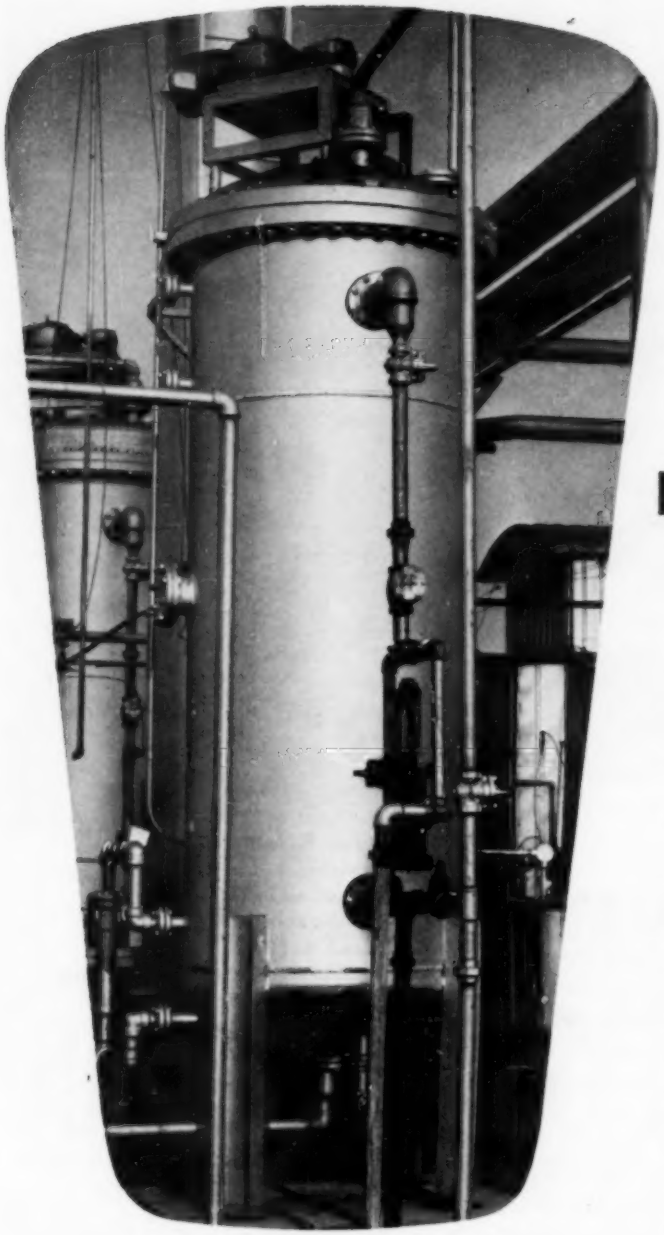
as near as your telephone

When your heat exchanger or condenser or other tubular equipment suddenly quits . . . IT'S AN EMERGENCY . . . you spin your phone dial . . . *and in minutes, day or night, Sundays or holidays, a CONSECO REPAIR CREW is speeding to your plant.* Expert, fast, doing in hours what otherwise would take days . . . they're equipped with special tools and all the tubes, tube sheets or specialties you need, drawn from our complete stocks. Yes, CONSECO SERVICE is as near as your telephone. *Call our Maintenance Department.*

CONDENSER SERVICE & ENGINEERING CO., INC. CONSECO

Designers and Builders of Equipment for Power, Refining, Chemical and Marine Industries

64 Bloomfield St., Hoboken, N. J.
HOboken 3-4425 or BArclay 7-0600



York-Scheibel columns for caustic treating of gasoline to remove mercaptans at Leonard Refineries, Inc., Alma, Michigan

YORK

YORK-SCHEIBEL multi-stage LIQUID-LIQUID EXTRACTORS

.... make solvent extraction
EFFICIENT • ECONOMICAL • PRACTICAL
for Laboratory, Pilot Plant and large-scale Industrial use.

The York-Scheibel multi-stage extraction column is highly efficient and practical for simple counter-current extractions. In addition, it is ideal for performing fractional liquid extraction operations, in which the feed material is simultaneously extracted by two selective and immiscible solvents. High stage efficiencies are obtained even with difficult to separate materials. Here are a few of the extractions for which York-Scheibel columns have no equal:

- close boiling mixtures
- azeotropic mixtures
- non-volatile mixtures
- materials from dilute solutions
- impurities and color bodies
- heat sensitive materials
- structural isomers

Check these outstanding features . . . available only with York-Scheibel solvent extractors:

- single, compact column
- high throughput capacity
- high efficiency
- low stage height; as many as 50 stages in a single column
- low cost per stage
- no internal bearings
- efficient laboratory, pilot plant and large scale performance.

Complete illustrated catalog on request.

YORK PROCESS EQUIPMENT CORP.
4 Central Ave. • West Orange, N. J.

Pump manufacturer *standardizes* on LATTICE BRAID* Packing for *all* centrifugal pump models

*Registered Trademark. *Only* Garlock makes LATTICE BRAID rod and shaft packings.

Peerless Pump Division, Food Machinery and Chemical Corporation, Los Angeles, manufactures an entire line of centrifugal pumps. Before changing to LATTICE BRAID, Peerless regularly received frequent complaints on packing from their customers. Now that Peerless has *standardized* on LATTICE BRAID, complaints are rare. In addition, Peerless reports that LATTICE BRAID *resists* the excessive gland pressure often applied by uninformed repairmen. The result is that there is *less* packing and sleeve wear.

Put Garlock LATTICE BRAID Packing to work for your company. All the braided strands of this unique packing are lattice linked together into one structural unit. The strands hold together even when the packing is worn far beyond the limits of wear of ordinary braided packings.

LATTICE BRAID is made from flax, cotton, asbestos, wire-inserted asbestos, Teflon, and asbestos with Teflon impregnation—for various types of services.

Get all the facts about LATTICE BRAID *Packings. Contact your Garlock representative or write for new folder AD-131.*

THE GARLOCK PACKING COMPANY, PALMYRA, NEW YORK

Sales Offices and Warehouses: Baltimore • Birmingham • Boston • Buffalo • Chicago • Cincinnati • Cleveland Denver • Detroit • Houston • Los Angeles • New Orleans • New York City • Palmyra (N.Y.) • Philadelphia Pittsburgh • Portland (Oregon) • Salt Lake City • San Francisco • St. Louis • Seattle • Spokane • Tulsa.

In Canada: The Garlock Packing Company of Canada Ltd., Toronto, Ont.

GARLOCK LATTICE BRAID PACKING

CANDIDATES

(*Continued from page* 58)

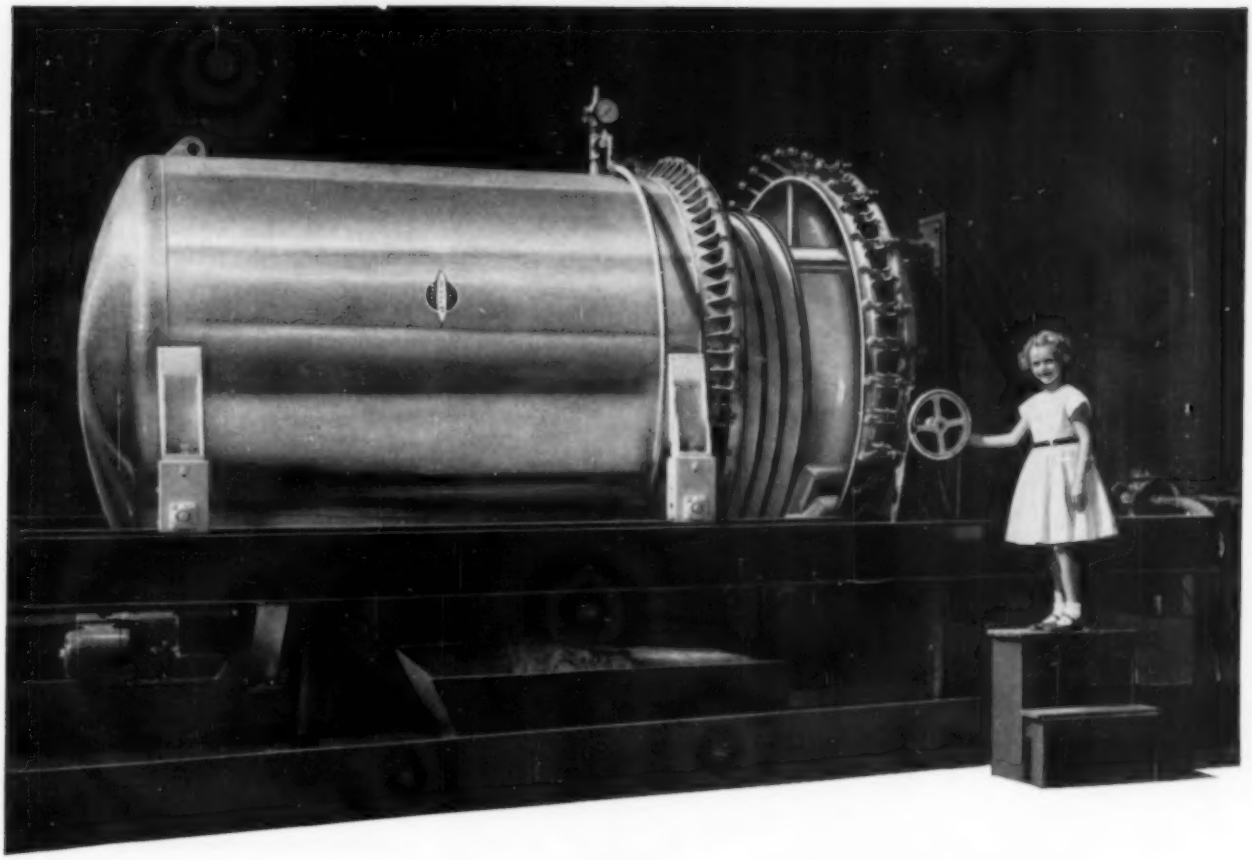
Russell, Robin A., *Monsanto, Tenn.*
Super, Wallace F., *Hopewell, Va.*
Young, Ralph M., *San Francisco, Calif.*

Associate

Aliberti, Vincent A., *Binghamton, N. Y.*
Aynardi, Leonard, *St. Louis, Mo.*
Baker, Robert A., *Springfield, Pa.*
Baur, Gerd R., *Decatur, Ala.*
Beaver, Richard H., *Denver, Colo.*
Blaine, H. Terrence, *San Francisco, Calif.*
Bonnell, Bayard H., *Mount Vernon, N. Y.*
Bracciano, Leo P., *Woodbury, N. J.*
Brooks, Judson M., Jr., *Philadelphia, Pa.*
Buckner, Lowell R., Jr., *Paulsboro, N. J.*
Chenoweth, R. G., Jr., *So. Charleston, W. Va.*
Cooper, Martin H., *Jacksonville, Fla.*
Cram, Kenneth H., *Pittsfield, Mass.*
Davis, Norval P., *Columbus, Ohio*
Dietert, Robert D., *Texas City, Tex.*
Dougherty, William J., *Wilmington, Del.*
Ebaugh, Burt, *Tioga, N. D.*
Geiger, Harvey A., *Army Chemical Center, Md.*
Girouard, Henry, *Wilmington, Del.*
Gulick, Charles W., *Westmont, N. J.*
Harrington, Richard Edward, *Circleville, Ohio*
Harvey, Leonard A., *Gary, Ind.*
Henderson, Herbert E., *Painesville, Ohio*
Johnson, Robert Lee, *Montclair, N. J.*
Johnson, Zane Q., *Port Arthur, Tex.*
Karmel, K. E., *Floral Park, N. Y.*
Klein, D. Michael, *Wilmington, Del.*
Knap, James E., *Charleston, W. Va.*
Krone, Lester H., Jr., *Jennings, Mo.*
Lapides, Jules S., *Fort Monmouth, N. J.*
Larson, Olaf A., *Midland, Mich.*
Lentz, Wolfdietrick F., *Clinton, Iowa*
Luchetti, Carlo A., *Mountain View, Calif.*
Malaxos, William, *Pittsburgh, Pa.*
Nimitz, Robert H., *Columbus, Ohio*
Noyes, Robert F., *Wilmington, Del.*
Pickles, Donald E., *New York, N. Y.*
Pike, E. Grant, *Rochester, N. Y.*
Rhodes, Robert P., *Pittsburgh, Pa.*
Rimmer, Jack, *Rensselaer, N. Y.*
Ringler, William H., *Maple Heights, Ohio*
Ruehl, Edward T., *Wilmington, Del.*
Sheets, Thomas M., *Newark, Del.*
Stokes, James T., *Houston, Tex.*
Storvick, Truman, *So. Charleston, W. Va.*
Uthman, Abdul-Rahman Ali, *Baghdad, Iraq*
Wehrly, Jack R., *Freeland, Mich.*
Weiss, Alfred J., *Fort Lee, N. J.*
Wiley, John S., *Albuquerque, N. M.*
Wilkinson, K. E., *Trois Rivieres, P.Q., Can.*
Wright, W. Reed, Jr., *Hopewell, Va.*

Affiliate

Parker, J. Royal, *New York, N. Y.*



IT'S CHILD'S PLAY

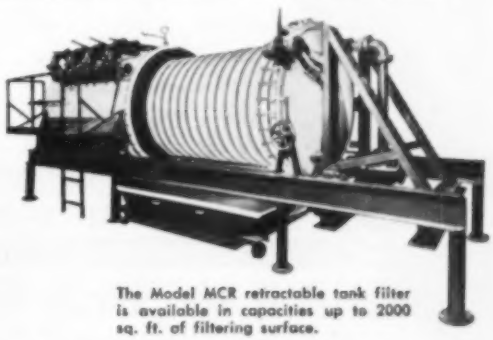
...to open up the MCR SPARKLER FILTER

The most effortless operated filter made. Talk about economy in operation; the labor and time saved alone in opening, cleaning and closing the MCR gives a running start in cost saving that puts you out ahead of manual operated filters. There is no labor problem with the MCR; operators love this filter.

Whether you are filtering heavy chemicals, primary filtration of beer, heavy oils, or any product with a high bulk residue you will find this power operated aristocrat of heavy duty filters faster, easier, and more efficient at every step in the filtering operation.

No breaking of pipe connections—self sealing cover gasket—complete drainage—smooth power retraction of the tank—are advanced, operating features that put this new filter in a class by itself.

Write Mr. Eric Anderson for engineering details of this filter as applied to your particular filtering problem.



The Model MCR retractable tank filter is available in capacities up to 2000 sq. ft. of filtering surface.

SPARKLER MANUFACTURING CO.

MUNDELEIN, ILL. • Sparkler International Ltd. • Plants at, Galt, Ontario, Canada; Amsterdam, Holland.

For over a quarter of a century, engineers and manufacturers of a complete line of industrial filtration equipment.

"J. B. seems less inhibited since he specified TEFLON* by Ethylene"

* DuPont trade name for tetrafluorethylene resin**

This amazing material is chemically inert, has excellent dieletric properties, resists heat and cold, is nonadhesive, and possesses great flexural strength. We make it in a great variety of sizes, of the finest quality, and for quick shipment. May our experts help you?

Write for Catalog C-2

** Converted by Ethylene into the best basic forms in the world, undoubtedly.***

EXTRUDED OR MOLDED RODS, TUBES, AND SPECIAL SHAPES. NON-POROUS SHEETS

*** We think.

"Pioneers and Specialists in TEFLON products"

ETHYLENE CHEMICAL CORPORATION

245 Broad St. - Summit, New Jersey

TECHNICAL PROGRAM

(Continued from page 38)

RECORRELATION OF DATA FOR CONVECTIVE HEAT TRANSFER BETWEEN GASES AND SINGLE CYLINDERS WITH LARGE TEMPERATURE DIFFERENCES, W. J. M. Douglas, and S. W. Churchill, Univ. of Michigan, Ann Arbor, Mich.

EFFECT OF VOID VOLUME AND PRANDTL MODULUS ON HEAT TRANSFER IN TUBE BANKS AND BEDS, Joel Weisman, Brookhaven Nat'l Laboratory, Upton, N. Y.

HEAT TRANSFER AND FLUID FRICTION IN A SHELL AND TUBE EXCHANGER WITH A SINGLE BAFFLE, F. W. Sullivan and O. P. Bergelin, Univ. of Delaware, Newark, Del.

TECHNICAL SESSION NO. 7

Industrial Relations Symposium

CHAIRMAN: Guy B. Arthur, President Guy B. Arthur and Associates, Inc.

PANEL MEMBERS: E. W. Dwyer, Director—Personnel Relations, Monsanto Chemical Co., St. Louis, Missouri; T.W. Collins, General Personnel Director, Pittsburgh Plate Glass Co., Pittsburgh, Pa.; one to be announced.

Wednesday, March 23, 1955

TECHNICAL SESSION NO. 8

(Simultaneous with Session No. 9)

CENTRIFUGATION SYMPOSIUM, J. O. Maloney, Presiding.

HYDROEXTRACTION—FLOW IN SUBMERGED CAKES, J. Anderson Storrow, Chem. Eng. Laboratory, College of Technology, Manchester, England.

VARIABLES AFFECTING THE APPLICATION OF CENTRIFUGALS, J. A. Schneider, Western States Machine Co., Hamilton, Ohio.

CENTRIFUGALS THAT ARE AVAILABLE AND THEIR GENERAL USES, Wm. C. Smith, Tolhurst Centrifugals Div., American Machine and Metals, Inc., East Moline, Illinois.

THE PRELIMINARY SELECTION OF CENTRIFUGAL EQUIPMENT—SURVEY AND DISCUSSION OF THE EQUIPMENT COMMERCIALLY AVAILABLE FOR LIQUID-LIQUID AND LIQUID-SOLID SEPARATIONS, J. B. Bingeman, Process Design Group, Ethyl Corporation, Baton Rouge, Louisiana.

PROCESS EVALUATION OF THE PUSH TYPE CONTINUOUS CENTRIFUGAL, Henry F. Irving, Baker Perkins Inc., Saginaw, Michigan.

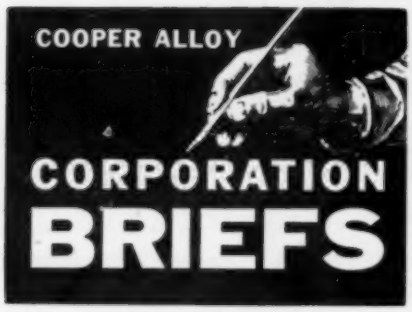
TECHNICAL SESSION NO. 9

(Simultaneous with Session No. 8)

PROPELLANT POWER SYMPOSIUM, R. A. Cooley, Presiding.

SMALL SCALE FACILITIES FOR DEVELOPMENT OF DOUBLE-BASE PROPELLANT, A. T. Camp, C. H. Carlton, Q. Elliott, and J. H. Weigand, U. S. Naval Ordnance Test Station, Inyckern, China Lake, Calif.

(Continued on page 66)



• Edited by GEORGE BLACK

DESIGN ENGINEERS CONFER

Two recent conferences at Cooper Alloy brought together almost two hundred of the nation's leading design engineers concerned with cast stainless steel products. The purpose of these conferences was fourfold: 1) to present data on new alloys 2) to review basic concepts of design in relations to the stainless steels 3) to present up-to-the-minute information on the shell molding of high alloys 4) to show how the cast weld method is being used to cut costs. The four technical papers were printed in the October 1954 issue of Newscast. Copies are still available on request.

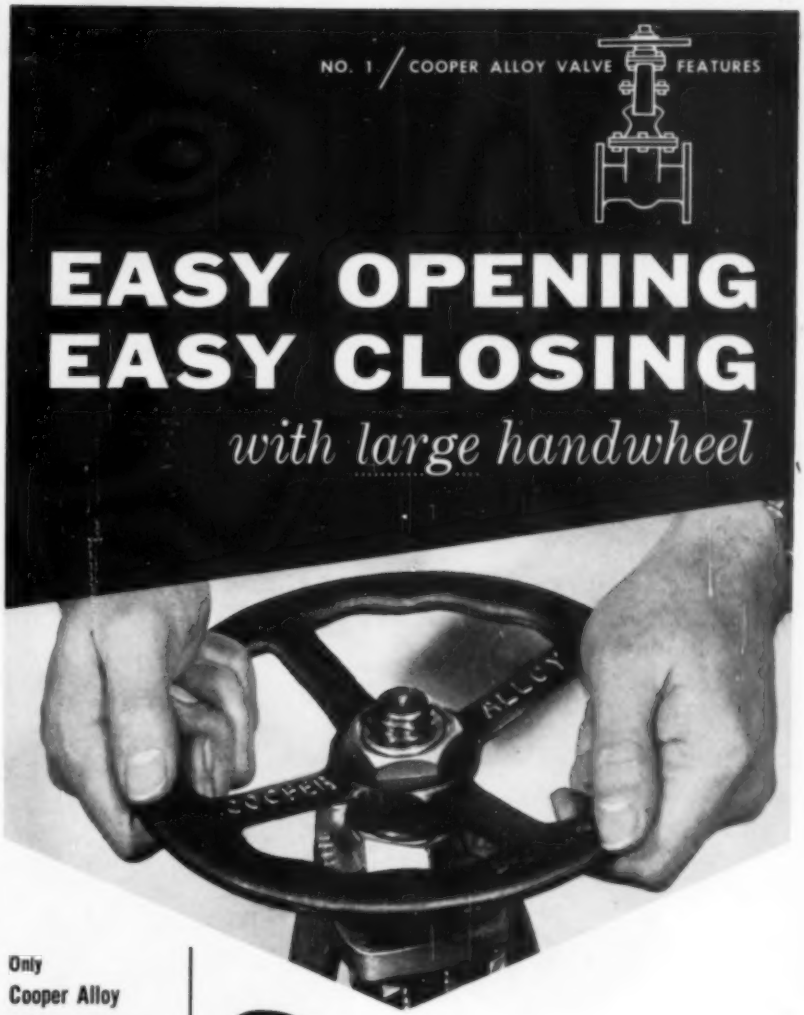
NEW VALVE CATALOG READY

More than two years in the making, the new COOPER ALLOY stainless steel valve catalog will soon be available. The design provides for an easy to use 64 page booklet, a more elaborate plastic bound shelf catalog, a deluxe looseleaf variation and a desk type card catalog. We can also supply you with individual catalog cards which can be marked and sent along with your order or quotation requests. Our representative will be happy to show you the various types available so that you can choose the one which best suits your needs. A phone call or letter will start him on his way.

ADVANCED KNOW-HOW SERIES

An interesting series of case histories showing how advance foundry technics have brought new dimensions to the scope of high alloy castings is being prepared by our Foundry Products Division. Each study will cover a specific part which because of its complexity or because of unusually high quality requirements, or both, presented a problem that couldn't be solved with conventional foundry practice. The methods used to achieve sound castings for these "castings which couldn't be cast" will be explained in detail. If you would like to receive this series as it is prepared, please drop us a note on your letterhead.

COOPER ALLOY
CORPORATION • HILLSIDE, N. J.



Only Cooper Alloy stainless steel valves have all these features!

1. Large handwheel
2. Extra heavy seats stems, discs
3. 100% x-ray of vital cast components
4. Centerless ground stem
5. Ball and socket rotating type discs
6. Extra deep stuffing box
7. Two-piece gland construction
8. Swinging eyebolts
9. Bowed yoke construction
10. Yoke cap designed for quick replacement

Stainless steel valves are precision instruments. When properly manufactured and cared for, they should open easily as well as provide tight closure. The Cooper Alloy line is designed with an oversized hand wheel to permit fatigue-free hand operation and to make unnecessary the use of wrenches, bars or other "persuaders" which may do serious damage to the disc and seat and multiply the possibility of galling.

New Catalog! A note on your company letterhead will reserve your new 1955 Cooper Alloy valve and fitting catalog.

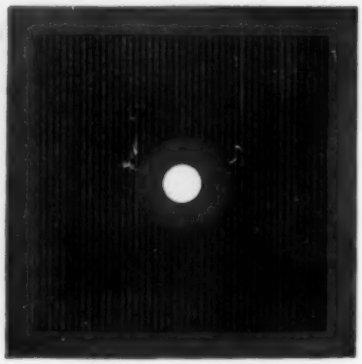
COOPER ALLOY
CORPORATION • HILLSIDE, N. J.
Valve & Fitting Division

Anti-Corrosive
WIRE CLOTH

- STAINLESS STEEL
- "NICHROME"
- "MONEL"
- PHOSPHOR BRONZE

for

- FILTER CLOTH
- SPECIAL PARTS
- STRAINERS
- SIEVES
- TRAPS
- SCREENS



Are you using wire cloth or wire cloth parts which must be corrosion resistant? Are the service conditions in your plant really tough? If you have a problem selecting the proper anti-corrosive alloy, Newark Wire Cloth may have the answer.

Available in all corrosion resistant metals, Newark Wire Cloth is accurately woven in a wide range of meshes, ranging from very coarse to extremely fine.

If you have a wire cloth problem involving corrosion, please tell us about it . . . we may have the answer.

NEWARK for ACCURACY

A complete line of woven wire cloth and wire cloth parts in all malleable metals.

Send for Catalog E

Newark Wire Cloth COMPANY

351 VERONA AVENUE • NEWARK 4, NEW JERSEY

TECHNICAL PROGRAM

(Continued from page 64)

PILOT PLANT DEVELOPMENT OF DOUBLE-BASE PROPELLANTS, E. R. Csanady and E. Roberts, Research and Development Dept., U. S. Naval Powder Factory, Indian Head, Maryland.

FULL SCALE PRODUCTION OF PROPELLANT, Robert W. Meglemre and Richard G. Guenter, Hercules Powder Co., Sunflower Ordnance Works, Lawrence, Kansas.

PROCESSING COMPOSITE ROCKET PROPELLANTS, Alfred J. Zaehringer, President, American Rocket Co., Wyandote, Michigan.

MECHANICAL WORK DONE IN 'COLLOIDING' DOUBLE BASE SHEET ON DIFFERENTIAL SPEED ROLLING MILLS, R. R. Buell, Liberty Powder Defense Corp., Badger Ordnance Works, Baraboo, Wisconsin.

TECHNICAL SESSION NO. 10

(Simultaneous with Session No. 11)

CENTRIFUGATION SYMPOSIUM, J. O. Maloney, Presiding.

EXTRAPOLATION OF PILOT PLANT CENTRIFUGE RESULTS, J. G. Glassen and R. W. Honeychurch, Merco Centrifugal Co., San Francisco, Calif.

THE HERMETIC SEPARATOR AND ITS APPLICATION TO INDUSTRIAL PROBLEMS, Frank E. Sullivan, Engineering Dept., The DeLaval Separator Co., Poughkeepsie, N. Y.

A SPECIAL DOUBLE-BOWL VACUUM CENTRIFUGE, John J. Meyers, and Albert Smith, Kodak Park Works, Eastman Kodak Co., Rochester, N. Y. and Julian C. Smith, Cornell University, Ithaca, N. Y.

THE DEVELOPMENT OF A CENTRIFUGE FOR CORN STARCH REFINING, C. M. Ambler, The Sharples Corp., Philadelphia, Pa.

TECHNICAL SESSION NO. 11

(Simultaneous with Session No. 10)

PROPELLANT POWER SYMPOSIUM, R. A. Cooley, Presiding.

CHEMICAL FACTORS IN PROPELLANT IGNITION, Melvin A. Cook and Ferron A. Olson, Explosives Research Group, University of Utah, Salt Lake City, Utah.

A TEST FOR ESTABLISHING THE RESIDUAL SAFE LIFE OF STABILIZED SOLID PROPELLANTS, Carl Boyars and W. G. Gough, Research and Development Department, U. S. Naval Powder Factory, Indian Head, Maryland.

THE INDUSTRIAL USE OF HIGH-ENERGY MATERIALS, C. H. Carlton, F. A. Warren, and J. H. Weigand, Southwest Research Institute, San Antonio, Texas.

COMPOSITION CHANGE IN BINARY COMPONENT SPRAY VAPORIZATION AT ATMOSPHERIC PRESSURE, J. F. Culverwell, Griscom-Russell Co., Chicago, Ill.; P. W. Grounds, Jr., Procter and Gamble Mfg. Co., Ivorydale, Ohio; H. Horn, International Minerals & Chemical Corp., Skokie, Ill.; and G. G. Lamb, Northwestern University, Evanston, Ill.

Addition to the 1954 Sky Line

NEW CAT-POLY UNIT for SOCONY-VACUUM

Recently turned over to the owners, Socony-Vacuum Oil Company, Inc., this modern phosphoric acid catalytic polymerization unit, under license from California Research Corporation, is currently producing high octane gasoline. Our engineering staff was responsible for complete design and erection.

This completion and the accompanying list of other current projects, will serve to emphasize the scope of our engineering service. It is as broad a service as the client wishes to utilize, including preliminary economic studies and competing process evaluations. It covers complete plants as well as processing units in the petroleum, petrochemical and chemical fields.

Should you assign us to work on *your* problem we would focus many years of engineering experience in the design of such processing plants and units plus the complementing experience of other important engineering services such as mechanical, electrical, structural, power and instrumentation.

Engineering

Design and Construction of Process Plants

•

Design and Construction of Process Units

•

Process Evaluations

•

Economic Studies

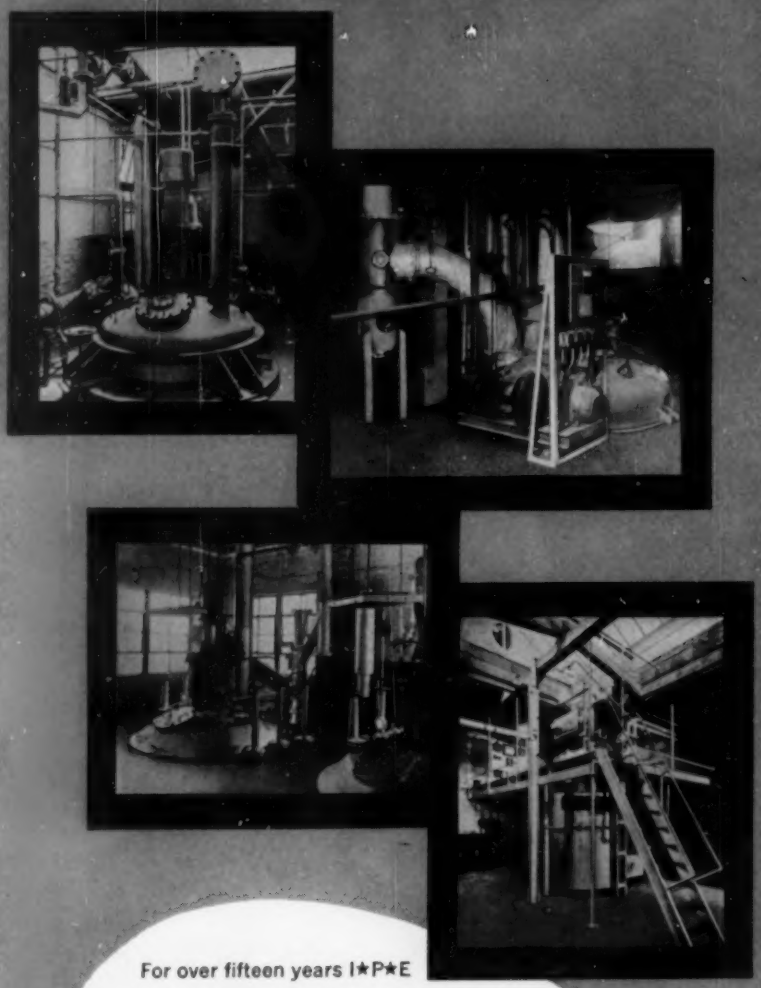
Other projects either recently completed or in advanced phases of design or construction include:

- Aromatics Recovery from Petroleum Stocks
- Separation of Para Xylene
- Synthetic Methanol and Ethanol Refining
- Naphthalene Purification
- Recovery of Acetic Acid
- Gasoline Treating
- Refinery Modernization

BADGER MANUFACTURING COMPANY

230 BENT STREET, CAMBRIDGE 41, MASS. 60 EAST 42nd STREET, NEW YORK 17, N.Y.

HOW MANY ALKYD PLANTS MAKE AN EXPERT?



For over fifteen years I★P★E has been providing complete alkyd resin installations to the world's leading chemical manufacturers. From Boston to San Francisco, from Capetown (Africa!) to Kalamazoo, I★P★E units are designed for Dowtherm, electricity, gas or oil heat, and are constructed in all types of stainless steel.

Like all I★P★E process plants, these are designed, engineered, constructed and installed by I★P★E. Other I★P★E specialties include plants for Fats and Oils... Fatty Alcohols...Resins...Soaps and Detergents... Fermentation Products...Pharmaceuticals... Medium Organic Chemicals...Esters...and many others.

For further information, write the Process Plants Division today.

INDUSTRIAL PROCESS ENGINEERS

71 LISTER AVE., NEWARK 5, N. J.

I·P·E

ENGINEERS, DESIGNERS, MANUFACTURERS OF PROCESSING PLANTS AND EQUIPMENT

NEWS

(*Continued from page 60*)

SUMMER COURSE ON REACTORS AT UNIVERSITY OF MICHIGAN

A two-week intensive course in nuclear reactors and radiations in industry will be given by the University of Michigan in Ann Arbor from August 15-26, 1955. The course is intended for the engineer without previous experience in nuclear technology who wishes to acquire a knowledge of representative problems and techniques in this rapidly developing field. Tuition will be $200.

The course will be sponsored by the Nuclear Engineering Committee of the College of Engineering, and will be conducted by members of the Engineering College staff. Participating will include Professors L. E. Brownell, H. J. Gomberg, W. Kerr, H. A. Ohlgren, and J. R. Sellars.

Lectures will cover theory, measurements, reactors, and fuels. The one megawatt research reactor will be under construction during the course, and will be inspected and discussed. Demonstrations using a multikilocurie gamma source will be conducted.

OAK RIDGE INSTITUTE ANNOUNCES SCHEDULE

The Oak Ridge Institute of Nuclear Studies has announced its schedule for 1955. The courses offered cover basic radioisotope techniques, industrial uses of sealed radioactive sources, and a survey medical course.

The next radioisotope techniques courses will be held from February 21 to March 18; May 2 to May 25; June 6 to July 1; July 11 to August 5; and August 15 to September 9. These courses are open to engineers and scientists in all fields and are designed for individuals starting work with isotopes.

The course on industrial uses of sealed radioactive sources will run from April 18 to April 29. It will be held in two sections—safe handling of sealed sources and industrial applications of sealed sources.

VITRO FORMS URANIUM COMPANY

The exploration, drilling and mining of uranium claims held by the Vitro Corporation of America and the Rochester & Pittsburgh Coal Company will be carried on by a new jointly owned subsidiary. The new company, the Vitro Minerals Corporation, will be equally owned by both companies and each will have an equal number of directors. Open pit mining of extensive claims in Wyoming are scheduled for early operation.

PROTECTED
BY 2,500,000 FILTER CHANNELS PER SQ. IN.!
A Celite Filter Cake is hundreds of times finer than the finest wire mesh!
PENICILLIN

In antibiotics: Celite® Filtration assures highest purity

Celite Filtration provides the critical purity required for antibiotics because it removes even the finest suspended solids. A Celite Filter Cake contains more than 2,500,000 filter channels per square inch of surface. The Celite method also provides high production volume because it permits fast flow rates.

Celite powders may be used with any type of conventional filter. The right balance between flow and capacity with degree of purity is easily achieved . . . first in building up a pre-coat of Celite on the filter medium, then by adding small amounts to the solution to form a continuously fresh filter surface. To meet different requirements, Celite comes in nine standard grades of microscopically controlled particle size. Utmost product uniformity is assured.

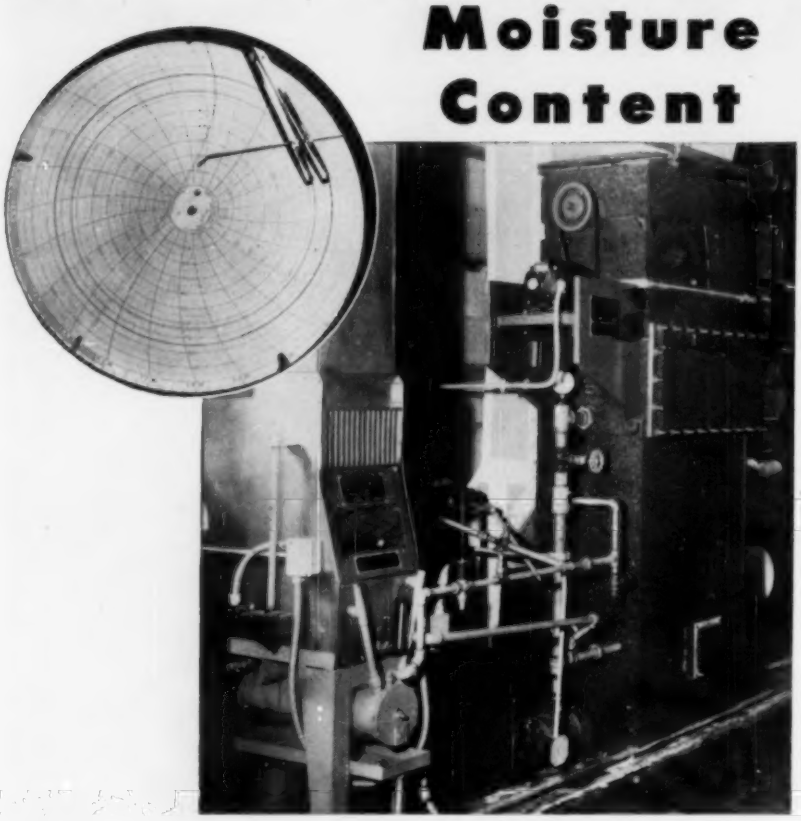
Because of its simplicity, flexibility and efficiency, Celite Filtration has become the standard for entire industries. For highest purity in antibiotics, for perfect clarity in food products, for removing impurities from chemicals, petroleum, and other products . . . Celite offers unequalled advantages.

Whatever filtration problem you face, it will pay you to investigate the Celite Filtration method now. A Johns-Manville Celite Filtration Engineer will gladly discuss your problem. For his services, without obligation, write Johns-Manville, Box 60, New York 16, N. Y. In Canada, 199 Bay St., Toronto 1, Ontario.

JOHNS-MANVILLE JM PRODUCTS

Johns-Manville CELITE FILTER AIDS

EXACT CONTROL of Moisture Content



. . . To Improve Your Product or Protect Your Materials or for Processes or Tests

● This Niagara Air Conditioning Method dries air directly and measurably, using a moisture-absorbing liquid spray. It makes humidity control a separate function from lowering or raising temperatures and gives you precise control with thermostats alone; no moisture-sensitive devices are needed. You have simpler, more trustworthy, less expensive control instrumentation. Niagara precise-control installations have the best record for reliability.

Niagara Air Conditioning provides you with any temperature and relative humidity you need. Using "Hygrol" absorbent, it is not expensive to operate, saving the refrigeration commonly used to condense moisture and making re-heat unnecessary in most cases. It gives large capacity with compact, easily-maintained equipment. Ask for Descriptive Bulletins #112 and #121. Address Dept. – EP.

NIAGARA BLOWER COMPANY

405 Lexington Ave. New York 17, N. Y.

District Engineers in Principal Cities of U. S. and Canada

Perkin Medal to Roger Williams

Roger Williams, vice-president of Dupont, was presented the 49th impression of the Perkin Medal of the American Section of the Society of Chemical Industry at the Waldorf-Astoria in New York on January 24.

In telling of some of Mr. Williams' most recent achievements Crawford H. Greenewalt, president of Dupont, cited Williams' key effort in the staggering task of the Hanford Atomic Energy Project during World War II. While no one man or even small group of men on this great team could be said to have made a major contribution, every team must have a leader, and Williams was the leader of the Dupont Company's undertaking. As such, he did much to set the spirit of the enterprise, who by example and precept induced all of his associates to do a little better than could be reasonably expected of them.

Reflecting upon his previous accomplishments which have been so material to the chemical industry, Mr. Greenewalt cited the major part Williams played as director of Dupont's pioneer effort in the field of high pressure nitrogen fixation for ammonia synthesis which resulted in the famed Belle, W. Va., works.

In his Perkin Medal address, Williams explained some of his working philosophy about the management of people. He cited that one of the greatest problems confronting management is how to provide a working climate conducive to achievement and personal satisfaction, and yet keep the door open to individual initiative. This is difficult because initiative and cooperation are antagonistic. Discovery and invention are highly individual matters whereas the great mass of technical effort is concerned with the elaboration of ideas which must be done largely through groups. Great emphasis is, therefore, placed on organization which even in companies of moderate size, tends to be specialized and complex. Ordinarily, an idea proposed by a worker is reviewed by various levels of supervision. This is time consuming, and often enthusiasm wanes. The remedy falls in greater delegation of authority to experienced supervisors who will appraise ideas not with the thought of bringing up every conceivable objection, but of offering encouragement or sympathetic discouragement, promptly and on an intimate personal basis. Above all, the originator should never be subjected to a technical court-martial.

CB&I FORMULA for Processing Problems:

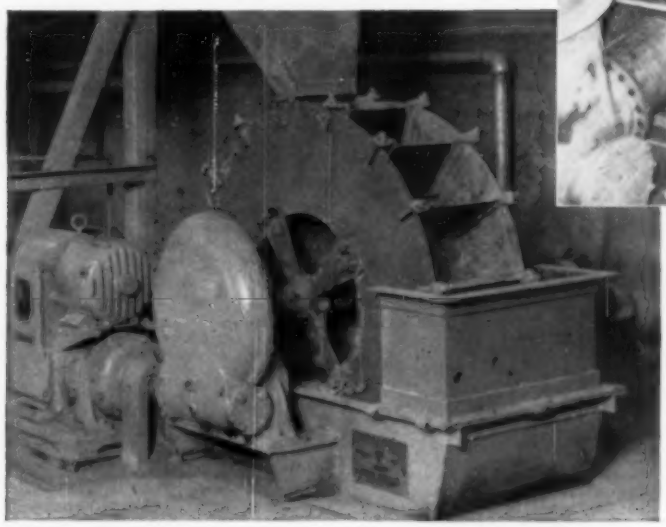
Conkey Crystallizers, Evaporators and Filters

Here is your prescription to remedy crystallizing, evaporating and filtering problems . . . Conkey designed and engineered equipment, fabricated in Chicago Bridge & Iron Company's four strategically located shops, and erected by CB&I experienced crews.

If your plant has a filtering, evaporating or crystallizing problem, write our nearest office. A Conkey engineer will be happy to assist with information, estimates or quotations.

Conkey all nickel construction Triple Effect Evaporator producing 50 per cent caustic liquor.

Conkey Triple Effect Vacuum Crystallizer producing ammonium sulphate.



Conkey Rotary Hopper Dewaterer in service dewatering abrasive grains.

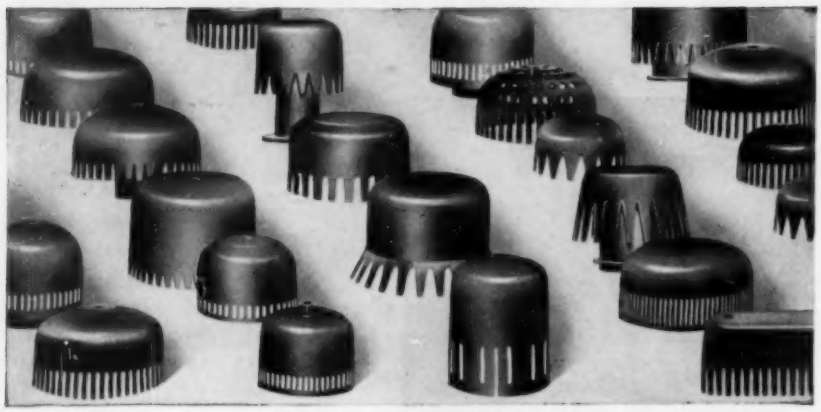
CHICAGO BRIDGE & IRON COMPANY

Plants in BIRMINGHAM, CHICAGO, SALT LAKE CITY and GREENVILLE, PA.

CONKEY EQUIPMENT

Atlanta • Birmingham • Boston • Chicago • Cleveland • Detroit • Houston
Los Angeles • New York • Philadelphia • Pittsburgh • Salt Lake City
San Francisco • Seattle • Tulsa • Washington

Schmieg
CENTRI MERGE
SPRAY BOOTHS
Efficient, Economical, Safe and Clean
Illustrated is a large haulaway truck in a Schmieg Centri-Merge Spray Booth designed and engineered to meet the most exacting operational requirement, which quickly demonstrates its superiority in the elimination of overspray.
Pigment and impurities are driven from the air stream by Schmieg Centri-Merge in a literal whirling tornado of water, removing the hazards of spray painting, giving top operational efficiency for many years at lowest maintenance cost.
When you are considering the installation of Spray Booths, Dust and Fume Control Equipment, Mechanical Washers, Industrial Ovens and Production Finishing Systems, be sure to call Schmieg engineers first.
Schmieg INDUSTRIES INC.
Engineers & Manufacturers
DETROIT, MICHIGAN
P. O. Address: 23930 Sherwood, Center Line, Mich.



SEND FOR PSC

BUBBLE CAP BULLETIN 21

Largest Compilation of Engineering Data.

Lists 200 Styles Furnished Without Die Cost.

This standard reference contains complete specification information for over 200 standard styles of bubble caps and risers. Also drawings for use in determining methods of tray assembly. All styles listed in Bulletin 21 are furnished promptly, without die cost, and in any alloy to meet your coking or corrosion problems. Special caps gladly designed; write as to your needs.

THE PRESSED STEEL CO., 708 N. Penna. Ave., Wilkes-Barre, Pa.

PSC

Custom Fabricators for the Process Industries Since 1928. Send Your Blue Prints

unionization of engineers

A panel on employment conditions and unionization and their effect on the engineer was attended by over 350 engineers who heard a summary of a statistical survey designed to determine the interests of the engineers in various constituent societies making up E.J.C. in organizing for collective bargaining purposes. Panels on Nuclear Engineering Developments, Engineering Manpower and the Service Opportunities for Engineers Joint Council were also part of the day long E.J.C. First General Assembly program held at the Hotel Statler, N. Y., on January 21.

That over 25% of engineers of various professional interests polled as to their opinion on collective bargaining have indicated that they were unopposed to such group action was brought out by G. B. Earnest, Vice-President of ASCE and President of Fenn College, in the panel on Employment Conditions and Unionization—Their Effect on the Engineer. He also discussed what collective bargaining agencies have found to be in their favor toward organizing engineers into unions.

Answering some of the problems arising between engineering and management on the collective bargaining issue E. L. Chandler, Assistant Secretary ASCE, discussed the responsibility of both groups in meeting this challenge. In summing up recommendations to management he said that if engineers truly are a present or prospective part of management, they must not be deemed as just industrial employees along with clerks, toolmakers, production-line operators and other classes of workers. However important these may be, the services of the engineer are far more distinctive and vital.

PFIZER TO OPEN PHILIPPINES PLANT

A new Pfizer plant for the production of Terramycin, Tetracyn and other pharmaceuticals is scheduled to begin operations in the Philippines early this spring. Pfizer has contracted for the reconstruction of a two-story manufacturing plant on the outskirts of Manila. Equipment is being shipped from the United States.

Plans for Pfizer's operations in the Philippines include a program of information and education for doctors and public health officials in the area to bring them the latest medical information. This will be done through monthly seminars.

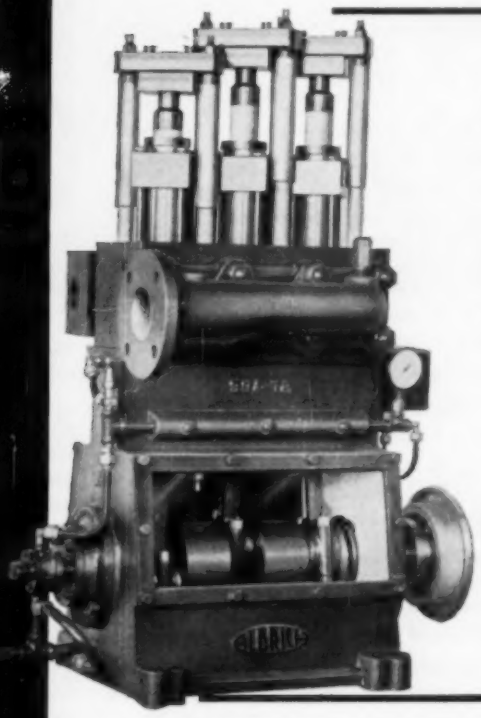
Reviews of New York meeting papers will begin in March issue.

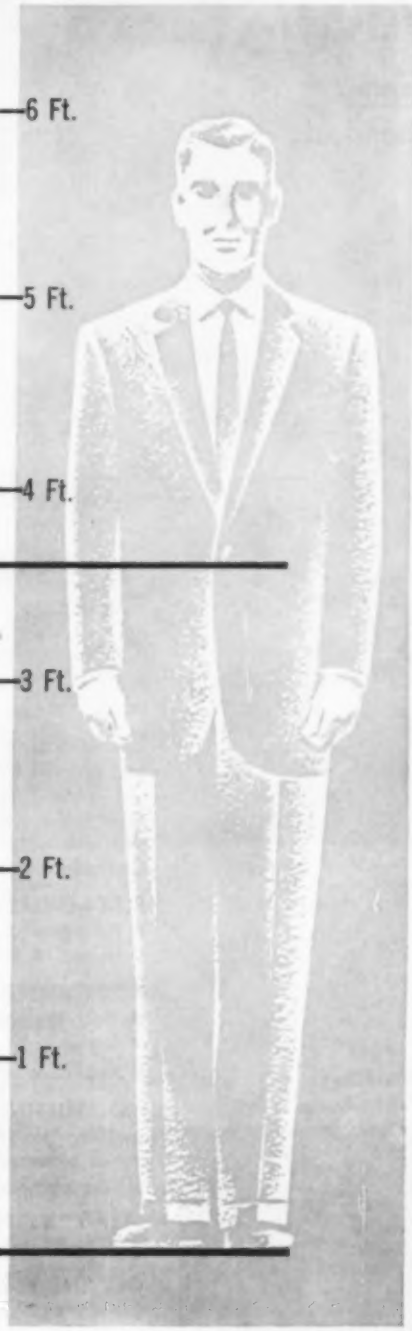
NEW "POWR-PAC"

2½" STROKE
25 HP
DIRECT
FLOW
ALDRICH
TRIPLEX
PUMP!

This latest addition to the Aldrich line embodies all of the outstanding features of design and construction that have made Aldrich Pumps famous—plus low cost. Rugged construction assures long, dependable service life. Sectional fluid-end design provides maximum economy in maintenance and repair. Write today for descriptive Data Sheet 63.

Sizes: plunger diameters from 2½" to 1½" for pressures from 390 psi to 20,700 psi. Displacement from 109.6 gpm to 2.08 gpm (3758 to 71 bbls/day).





APPLICATIONS

DESCALING
DIE CASTING
ROLL BALANCING
WATER FLOODING
PRESS OPERATION
HYDRAULIC TESTING
CHEMICAL PROCESSING

the ALDRICH *pump company*

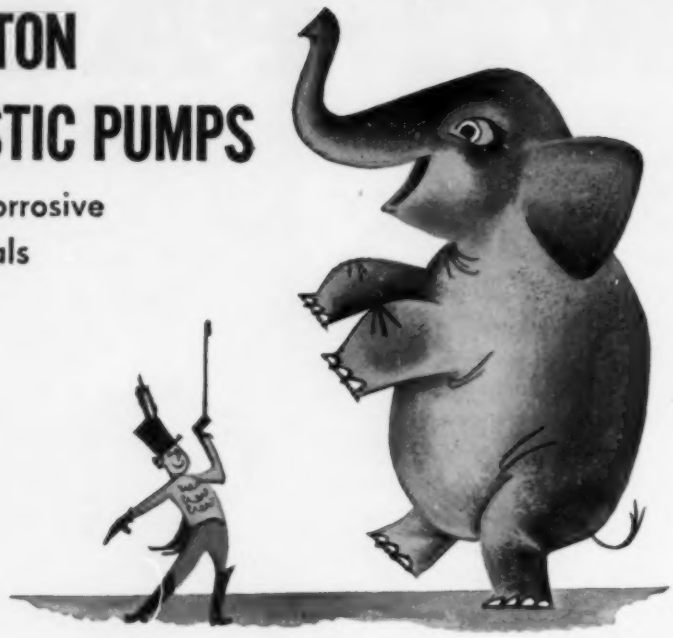
. . . Originators of the Direct Flow Pump

20 GORDON STREET • ALLENTOWN, PENNSYLVANIA

Representatives: Birmingham • Bradford, Pa. • Boston • Buffalo • Carmi, Illinois • Charleston, W. Va. • Chicago • Cincinnati • Cleveland • Dallas • Denver • Detroit • Duluth Houston • Los Angeles • New York • Oakland, Calif. • Philadelphia • Pittsburgh • Portland, Ore. • Richmond, Va. • Rochester • Salt Lake City • San Francisco • Seattle Somerville, Mass. • Spokane, Wash. • Syracuse • Tulsa • Washington, D. C. • Youngstown • Export: Petroleum Machinery Corp., 30 Rockefeller Plaza, New York 20, N. Y.

VANTON PLASTIC PUMPS

tame corrosive chemicals



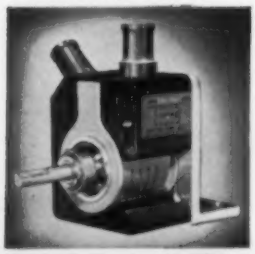
Flex-i-liner **PUMPS** are becoming industry's standard for those difficult to handle corrosive solutions and abrasive slurries, such as HCL, HF, NaOH, H_2SO_4, distilled H_2O, $FeCl_3$, HCOOH, and $Al_2(SO4)_3$, because their unique design eliminates stuffing boxes, shaft seals, gaskets and check valves.

NO METAL IN CONTACT—The only parts in contact with the fluid being pumped are the outer surface of the durable precision molded flexible liner and the inner surface of the pump body block, both of which are available in a wide selection of corrosion and contamination resistant materials.

FLEX-I-LINERS:
● Pure gum rubber ● Natural Rubber ● Neoprene
● Hycar ● Buna N ● Silicone ● Vinyl ● Compar

BODY BLOCKS:
● Polyethylene ● Bakelite ● Buna N
● Lucite ● Unplasticized PVC
● Available in stainless steel for special applications.

Flex-i-liner
Plastic Pump



NO STUFFING BOX—Elimination of stuffing boxes, packing glands and shaft seals, avoids the possibility of external leakage and prevents contamination of the transferred liquid by oil or grease.

SELF PRIMING—Vanton self priming plastic pumps give immediate operation in any position.

GET THE FACTS—Write for bulletin "VP" and the full story of Vanton plastic pumps

OUR CORROSION RESISTANT PRODUCTS FOR FLUID HANDLING include a complete line of Buna N and Natural Hard Rubber centrifugal pumps, valves, pipe and fittings. Bulletin BHR on request.

VP

VANTON
PUMP & EQUIPMENT CORP.
201 SWEETLAND AVE. • HILLSIDE, N. J.

NEW ENGLAND GETS ANHYDROUS AMMONIA PLANT

Construction of the first anhydrous ammonia plant for New England has been announced by Northern Chemical Industries. A $9,000,000 plant will be located at Searsport, Maine, adjacent to the site of Northern Chemicals' present operations which are one of the only North American plants with integrated mixed fertilizer, superphosphate and other raw material manufacturing facilities. This will be the first plant using exclusively the Texaco-Hydrocarbon Research Process for producing ammonia synthesis gas from Bunker "C" fuel oil by partial oxidation with oxygen.

A contract to erect the 125-ton/day anhydrous ammonia plant, a 60-ton/day nitric acid plant, a complete nitrogen solutions plant and a 7,500-kw. power plant has been awarded to the Girdler Co. The new project will be completely self sustaining.

Of an expected 43,000 tons of ammonia produced per year, about 18,000 tons will be used in the production of some 32,000 tons of nitrogen solutions to be used in fertilizer manufacture. The balance of the ammonia will be sold to sulfite pulp producers, a large number of which are located in close proximity to Searsport, Maine.

It is understood that the ammonia synthesis unit will be scaled up from the Texaco pilot plant through the use of a number of parallel operated catalytic converters, each the size of the pilot plant unit.

CHEMICALS TO CORNFIELDS

(*Continued from page* 40)

neither natural or chemical fertilizers have been used very widely, at least, until recently. Today, the extensive mechanization of the farm has increased so greatly the capital investment per productive worker, as to exceed in many instances that of highly mechanized industry. This has pushed up the farmer's break-even point to a level where any means for increasing the output from his soil begins to look attractive.

Then too, many of these acres have been tilled for scores of years without return of nitrogen even through legume crop rotation. Some of this soil is therefore ready for chemical replenishment.

F.O.B. Tuscola

Reduction of the cost of ammonia and nitrogen solutions in the upper Mississippi valley has been the immediate result of the operation of a plant by USI at Tuscola. The reason has to do with freight rates; Tuscola is now the northern-most freight equalization point.

(*Continued on page* 78)

What Cuts Labor Cost 50%?

What Cuts Moisture to 0.1%?

What Cuts Drying Time 90%?

Operator loads Rotary Vacuum Dryer in Stokes pilot plant.

Labor and time are reduced 50% by vacuum drying of a mixture of acetyl salicylic acid and other chemicals.

Sodium trichloracetate is reduced from 35% to 0.1% moisture content in 8 to 12 hours by vacuum drying.

Several makers of powdered aluminum and brass avert fire and explosion hazards by drying powders and solvents in vacuum . . . then recover 99% or more of the solvent in the same process.

Shellac is dried in vacuum in 6 to 8 hours per batch, a job that formerly took 72 hours!

Stokes has the laboratory and pilot plant facilities to test vacuum drying of any product which offers drying difficulties. Methods, cycles, equipment, costs will be accurately determined. Stokes has 40 years' experience in vacuum technology to share with you on drying problems.

Send for an informative brochure, "Vacuum Drying," on the techniques of moisture removal from chemicals, pharmaceuticals and other industrial products.

F. J. Stokes Machine Company
Philadelphia 20, Pa.

STOKES

STOKES MAKES: High Vacuum Equipment, Vacuum Pumps and Gages / Industrial Tabletting, Powder Metal and Plastics Molding Presses / Pharmaceutical Equipment

TAYLOR COMPARATORS

"never knew pH, CHLORINE, PHOSPHATE TESTS could be so easy!"

Just fill 3 test tubes with the sample to be tested and place them in the base...

add reagent to middle tube only...

place color standard slide on base. Move the slide across until the colors match and...

There's the Value!

You can make pH, chlorine, phosphate or nitrate determinations with these 3 easy steps with Taylor Comparators. Complete water analysis, including fluorides, is only a little more detailed when you use a Taylor Water Analyzer. Taylor sets are lightweight, durable, portable. Many different tests can be made on a single base. Best of all . . .

COLOR STANDARDS ARE GUARANTEED

Taylor liquid color standards carry an unlimited guarantee against fading, thus there's no chance of mechanical inaccuracy. Since a complete set of standards for any one determination is enclosed in a sturdy plastic slide, there's no need to handle fragile single standards.

SEE YOUR DEALER for Taylor sets or write direct for **FREE HANDBOOK, "Modern pH & Chlorine Control."** Gives theory and application of pH control, illustrates and describes full Taylor line.

SERVING SCIENCE AND INDUSTRY 1930 1955 FOR 25 YEARS

W. A. TAYLOR AND CO.
412 RODGERS FORGE RD. • BALTIMORE 4, MD.

Grace's new nitrogen plant. Towers in foreground, from l. to r., are the synthesis gas caustic scrubber, CO_2 absorber, and MEA reactivators.

Grace Chemical dedicates first plant

The first manufacturing unit of the Grace Chemical Co., a subsidiary of the W. R. Grace & Co., was opened in December with the production of its first tank carload of anhydrous ammonia. The new $20,000,000 plant located near Memphis, Tenn., will market ammonia in the mid-south region and lower corn belt area, and urea, for fertilizer use, internationally.

Construction of the plant which will have an annual capacity of 90,000 tons of ammonia and 54,000 tons of urea was under the supervision of Foster Wheeler Corp. The plant, which was located in the Memphis area because of its position as the center of a large and growing market, and its advantages of rail and water transportation, will employ about 235.

In the production of ammonia and urea the Grace plant employs an air separation unit, designed by Air Products, Inc., to furnish pure oxygen and nitrogen, the Texaco Partial Oxidation Process for the manufacture of hydrogen, the Casale Ammonia Process for the production of ammonia, and the Perchiney Process for the manufacture of urea.

These processes require just three raw materials for the production of ammonia and urea-natural gas which is received by pipeline, and air, and water —which are drawn from the immediate surroundings.

In the gas manufacturing process air is compressed to about 600 lb./sq.in., scrubbed with caustic to remove carbon dioxide and dried. It is then sent to the air separation plant where it is liquified and separated by distillation into nitrogen and oxygen.

Hydrogen is formed by compressing oxygen mixed with natural gas in the Texaco units where the methane is partially burned. The temperature and pressure in these units reaches 2,000° F. and 300 lb./sq.in. The hydrogen is quenched with water to reduce its temperature and is then mixed with steam in shift converters, where with the aid of a catalyst the carbon monoxide is converted to carbon dioxide.

Removal of the carbon dioxide from

(*Continued on page 77*)

GRACE CHEMICAL

(*Continued from page 76*)

the hydrogen stream is by absorption in monoethanolamine which is later stripped for the carbon dioxide. The carbon dioxide is used as a raw material for the production of urea.

The hydrogen is purified finally by scrubbing with caustic, drying, and finally washing with liquid nitrogen supplied by the air separation plant. These steps remove the last traces of carbon dioxide, water, methane, argon, and carbon monoxide. Although some nitrogen remains in the hydrogen stream after the nitrogen wash there is not enough to produce a proper ratio for ammonia production. Additional nitrogen from the air plant is added to achieve a hydrogen-nitrogen ratio of 3 to 1 and the resultant synthesis gas is compressed to 8,000 to 12,000 lb./sq.in. At this pressure the reactants are passed over a catalyst in the Casale units to form ammonia.

The Casale ammonia system is unique in that the unreacted gases are recirculated by an ejector rather than by a compressor. The high pressure employed allows the condensation of the synthesized anhydrous ammonia at normal cooling water temperature rather than requiring the use of refrigeration.

After synthesis and condensation the ammonia is either stored directly as anhydrous ammonia or is absorbed in water and stored as an aqueous solution.

The Urea plant uses carbon dioxide and ammonia as raw materials. Carbon dioxide is obtained from the MEA stripper and is compressed, preheated, and purified to remove traces of sulfur and oxygen. The ammonia and carbon dioxide are sent to the urea autoclave where, in an oil medium and under about 3,000 lb./sq.in. pressure, they are reacted to form urea.

The presence of oil in the autoclave forms the basis of the Perchiney urea process. The oil coats the walls of the autoclave and reduces corrosion, provides a means for controlling the temperature of the reaction, and provides a means of recycling; carbon dioxide and ammonia which do not react during the first pass through the synthesis system.

The material from the reaction autoclave is sent to a stripper tower where the unreacted raw materials are removed at the top of the tower. The unreacted ammonia and carbon dioxide are recombined in an oil slurry in a reactor and recycled to the autoclave. The bottoms from the stripper are separated into two layers in the decanter. One of these layers consists of urea dissolved in water; the other is oil.

The water solution of urea obtained

(*Continued on page 94*)

Quality Fabrication
is our Business
Whether its a kettle, reboiler, reactor or other process equipment, Manning & Lewis engineers and craftsmen are ready to design and fabricate a unit, tailor-made to fit your particular process need, and priced to fit your budget.
You need only supply the performance requirements. An experienced M & L engineer will take it from there and specify type, size, method of construction, etc.—all the essentials that have made Manning & Lewis equipment preferred in plants from coast to coast.
Send your inquiry or have a M & L representative call.
Manning & Lewis
Engineering Company
30 Ogden Street
Newark 4, New Jersey
M&L

FOAM'S A THIEF

KILL IT *with* DOW CORNING ANTIFOAM AF EMULSION

Now you're the boss! Foam no longer dictates productive capacity, output or processing times as witness these examples:

- ***strawberry concentrate cooling time reduced 25%.***
- ***dairy saves 300-400 gallons of skimmed milk daily.***
- ***yield on textile vat dyes doubled.***
- ***vacuum concentration capacity increased 60%.***

Effective at remarkably low concentrations against the widest variety of foamers, Dow Corning Antifoam A and the more easily dispersed Antifoam AF Emulsion are physiologically harmless; pay for themselves many times over because they ● ***eliminate the waste and fire hazard of boil-overs*** ● ***reduce processing times*** ● ***save the space previously wasted on foam in process equipment***

see for yourself! mail coupon TODAY for **free sample**

DOW CORNING SILICONES

Dow Corning Corporation
Midland, Mich., Dept. 3002

Please send me data and a free sample of
☐ Dow Corning Antifoam A
or ☐ Dow Corning Antifoam AF Emulsion

NAME_____
COMPANY_____
ADDRESS_____
CITY_____ ZONE____ STATE____

CHEMICALS TO CORNFIELDS

(*Continued from page 74*)

Previously, the Chicago mixed-fertilizer manufacturer bought his anhydrous ammonia f.o.b. Henderson, Ky., regardless of location of supplier. For solutions, it was either fob South Point, O., or Pittsburg, Kans.

How National got into heavy chemicals

Far more complex than simply deciding to make ammonia at Tuscola, was the path taken by the large whiskey-making firm in building a staff and making contacts to enable it to market fertilizer products.

National's fertilizer story begins with the decision, in 1949, to enter the sodium field. The story, according to National's president John Bierwirth, has to do with processing-technologist Bob Hulse, who at the time of the sodium operations envisioned and sold National's management on the petrochemical venture which became known as "operation Tuscola." This not only cost upwards of $50 million and resulted in extensive diversification of the parent firm—it also proved to be a highly successful business venture. Today, technologist Bob Hulse is a member of top management, as vice-president and director of chemical divisions, as well as a member of the board of directors of National Distillers Products Corp.

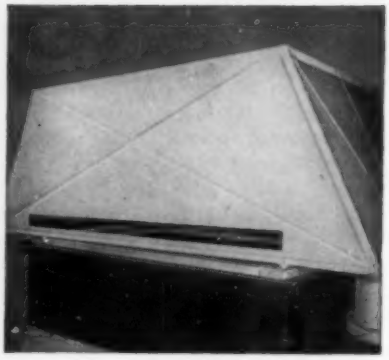
Following the sodium venture, and while Tuscola was in the early planning stage, National acquired U. S. Industrial Chemicals Co., a major diversified chemical marketing and manufacturing organization. First project for the USI staff was to market a large portion of Tuscola's alcohol output.

Next step on National's part was to acquire heavy chemical manufacturing facilities. This was done through purchase of Algonquin Chemical Co., and the transaction included transfer to National of Algonquin's contracts to supply sulfuric acid to its customers—largely mixed fertilizer manufacturers. One of the prime reasons for the purchase, however, was to assure the Petro works of adequate sulfuric acid for the alcohol synthesis and chlorine for ethyl chloride. At the time, both were in short supply. Later, however, USI built a sulfuric plant at Tuscola to take care of Petro's needs.

With these developments the USI staff was getting under way with the marketing of heavy chemicals—something not previously in their line of experience. Soon it was an easy step to survey those sulfuric acid customers making mixed fertilizers, to determine whether they could be sold Tuscola ammonia and nitrogen solutions, if and when they would be made there.

(*Continued on page 79*)

THIS PLA-TANK® HOOD SAVED ITS COST IN A YEAR



The PLA-TANK Hood shown above has been in continuous use at General Electric's small aircraft engine department in West Lynn, Mass., for over a year. Reports indicate that it is still as good as when originally installed, is already credited with saving its entire cost since no previously used material had lasted over a year.

The tank is used for etching stainless steel billets; solutions used are aqua regia at room temperature and a 50% solution of muriatic acid at 180°F. PLA-TANK has successfully withstood these fumes, where other materials failed.

PLA-TANK products are daily solving problems of all types in the chemical and electroplating fields. They replace or outlast stainless steel, lead and ceramic linings, plywood coated with corrosion preventatives, phenolic plastics and asbestos cement board structures in many applications.

PLA-TANK, molded from long-life, resin-bonded glass fibre laminate, is now resistant to a wider variety of fumes and temperatures than ever before. PLA-TANK is light weight, easy to install, competitively priced.

Let us help you solve your problems the modern way — with PLA-TANK. Write today for free data sheets.

P-21

THE *Chemical* CORPORATION
73 Waltham Ave., Springfield 9, Mass.

THIS IS REALLY

FUTURE MEETINGS and

CHEMICALS TO CORNFIELDS

(*Continued from page 78*)

The survey proved affirmative and the decision was made to build the plant at Tuscola. This relieved Bob Hulse of a previously bothersome problem of having to burn as a fuel the hydrogen produced as a by-product in the ethylene unit, in which ethane is cracked to ethylene.

The ammonia plant was designed by the M. W. Kellogg Co. of New York, at a rated capacity of 50,000 tons/year. This figure was arrived at on the basis of the hydrogen available as a by-product, providing that Petro's ethylene production would be at full rated capacity (and at a cost figured on its replacement with conventional fuel).

As it has turned out, this hydrogen availability figure has neither been adequate nor static for the following reasons: First, the Kellogg firm is now certain from experience with a similar plant elsewhere, that the Tuscola ammonia plant will have a considerable higher capacity than was thought when designed. This will call for additional hydrogen. Then, too, the volume of hydrogen originally estimated as available from the ethylene unit has been reduced as the result of a decision to start initially the new polyethylene plant (under construction) at 25 instead of 50 millions lb./yr. rated capacity.

These factors have indicated the advisability of having the Gas Process Div. of Girdler (Louisville, Ky.) go ahead with design and construction of a natural gas reformer unit adjacent to the ammonia plant, to produce the extra hydrogen as needed. This is expected to be operating by year's end.

The by-product hydrogen contains 20% impurities, of which the hydrocarbons are removed by chilling, and the CO and CO_2 by liquid nitrogen scrubbing. The nitrogen comes from an air liquefaction plant designed and built by L'Air Liquide, Montreal, Can., and their U. S. affiliate, Spaco, Inc., of New York. Additional nitrogen mixed with the hydrogen becomes synthesis gas which is fed directly to the catalytic converter. Oxygen of 95% or better purity and argon, both byproducts of the air liquefaction plant, are used elsewhere and sold commercially, respectively.

The compressor house serving both air liquifaction and ammonia plants contains only reciprocating compressors. Clark and Brown-Boveri machines compress air; Worthingtons handle refrigerant, nitrogen and fuel gas; and Cooper Bessemers are used with synthesis gas.

Only part of the anhydrous ammonia will be sold commercially as such; most will be converted into the "nitrogen

(*Continued on page 90*)

DOYLE & ROTH

standard stainless steel

VAPOR CONDENSER

MODEL VT

STANDARDIZED

To insure LOWER PRICES, FAST DELIVERY.

DESIGNED

To meet the exacting requirements of the chemical and process industries.

D & R passes on to you the economies accruing from its standardization program. Starting with engineering and following through on construction, economies are substantial. Materials are purchased to rigid specifications and standard components are stocked. ASME standards govern fabricating procedures.

Standardized equipment PAYS . . .

★ LOW FIRST COST,
★ PROMPT SHIPMENT,
★ EASILY REPLACEABLE PARTS obtainable from stock.

Mail this coupon today for detailed literature!

DOYLE & ROTH Manufacturing Co., Inc.

140 Twenty-fourth Street, Brooklyn 32, N. Y.

CEP-255

Please send further information and details on D. & R. Model VT-Vaper Condenser.

FIRM NAME .....

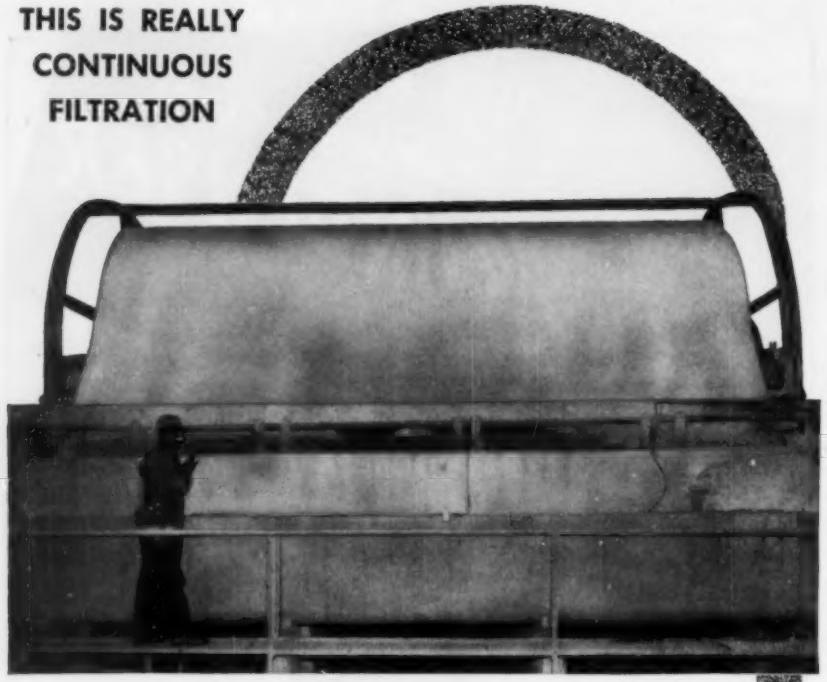
INDIVIDUAL .....

ADDRESS .....

CITY .....ZONE .....STATE.....

Symposia of the Institute

THIS IS REALLY CONTINUOUS FILTRATION



21 FEET OF UNBROKEN FILTER CAKE

24 HOURS A DAY . . . with FEinc STRING FILTERS

The clean, unbroken sheet seen here is composed of refined kaolin which is coming off the discharge end of a FEinc String Filter at J. M. Huber Corporation, Huber, Ga. The uniformly dewatered cake, although of a sticky character, is cleanly lifted from the revolving filter drum by closely spaced strings which carry the clay blanket to the discharge roll, where it drops into the trough.

The FEinc String Filter is successfully delivering cleaner, dryer cakes with materials ranging all the way from thin, soupy slimes, colloidal gels, greasy waxes, etc., to flocculent, fibrous or crystalline cakes . . . with less "down time" and lower maintenance costs. In a surprising number of cases this FEinc is the most economical of all filters for the "easy" jobs as well as the tough ones.

The FEinc String Discharge Filter is only one of many continuous filters now made by Filtration Engineers. Our engineering service is the finest available, backed by 35 years of experience, and backed by the ability to deliver filters that are tailor-made to fit the job . . . at no more than standard costs. Write or telephone us today for more details.

Test the actual performance of FEinc . . . at low cost . . . rent this small pilot-plant filter with interchangeable string or scraper discharge. Write for facts.

Filtration Engineers, Inc.

CUSTOM DESIGNERS AND MANUFACTURERS OF ALL TYPES OF CONTINUOUS FILTRATION EQUIPMENT

FEinc

42 **155 ORATON STREET • NEWARK 4, N. J.**

FUTURE MEETINGS and

MEETINGS **SYMPOSIA**

■ **LOUISVILLE, KY.**

March 20-23, 1955. Kentucky Hotel.

TECHNICAL PROGRAM CHAIRMAN: R. M. Reed, Tech. Dir., Gas Proc. Div., The Girdler Corp., Louisville 1, Ky.

Heat Transfer—Joint with A.S.M.E.

CHAIRMAN: R. L. Pigford, Div. of Chem. Eng., Univ. of Delaware, Newark, Del.

Propellant Power

CHAIRMAN: R. A. Cooley, Explosives Div., Olin Mathieson Chemical Corp., East Alton, Illinois.

Industrial Relations

CHAIRMAN: Guy B. Arthur Jr., Industrial Consultant, Toccoa, Ga.

Centrifugation

CHAIRMAN: J. O. Maloney, Chairman, Dept. Chem. Eng., Univ. of Kansas, Lawrence, Kan.

Solvent Extraction

CHAIRMAN: Dr. R. B. Beckman, Dept. Chem. Eng., Carnegie Inst. of Tech., Schenley Park, Pittsburgh 13, Pa.

Deadline Past

■ **HOUSTON, TEXAS**

May 1-4, 1955. Shamrock Hotel.

TECHNICAL PROGRAM CHAIRMAN: J. L. Franklin, Res. Assoc., Humble Oil & Refining Co., P. O. Box 1111, Baytown, Texas.

Nucleation Processes

CHAIRMAN: D. W. Oakley, Plant Mgr., Metal & Thermit Corp., 1 Union St., Carteret, N. J.

Flow of Fluids Through Porous Media

CHAIRMAN: H. Dayton Wilde, Mgr. Res. Div., Humble Oil & Ref. Co., Box 2180, Houston 1, Tex.

Extractive and Azeotropic Distillation

CHAIRMAN: Dr. D. E. Holcomb, Dean of Eng., Texas Technological College, Lubbock, Tex.

The Chemical Engineering Curriculum

CHAIRMAN: Dr. J. W. Mason, Dean of Eng., Georgia Inst. of Tech., Atlanta, Ga.

Differences in Chemical Engineering Theory

CHAIRMAN: Dr. F. A. Landee, Dow Chemical Co,. Midland, Michigan.

Deadline Past

■ **LAKE PLACID, N. Y.**

Sept. 25-28, 1955. Lake Placid Club.

A meeting devoted to the problems of interest to top management.

NOTE—No general papers

TECHNICAL PROGRAM CHAIRMAN: L. J. Coulthurst, Mgr. Proc. Engr., Foster Wheeler Corp., 165 Broadway, New York 6, N. Y.

Chemical Engineering Organizations

CHAIRMAN: J. F. Thornton, Pres., The Lummus Co., 385 Madison Ave., New York 17, N. Y.

Growth of the Oil & Chemical Industry by Integration

CHAIRMAN: Mr. F. M. Simpson, Petroleum Chemicals Inc., 54 Wall St., New York 5, N. Y.

Packaged Power

CHAIRMAN: H. Arthur Martin, Exec. Vice-Pres., J. F. Pritchard Co., Kansas City, Mo.

Deadline—May 25, 1955

Atom Profits

A symposium to be sponsored by the Nuclear Engineering Division.

■ **ANNUAL—DETROIT, MICH.**

Nov. 27-30, 1955. Statler Hotel.

TECHNICAL PROGRAM CHAIRMAN: T. J. Carron,

Symposia of the Institute

MEETINGS **SYMPOSIA**

Supervisor, Chem. Eng. Section, Ethyl Corp., Res. Labs., 1600 West Eight Mile Road, Detroit 20, Mich.

Photochemical Processes

CHAIRMAN: Prof. J. J. Martin, Dept. Chem. Eng., Univ. of Michigan, Ann Arbor, Mich.

Biochemical Engineering

CHAIRMAN: Dr. H. O. Halvorsen, Dept. of Bacteriology, Univ. of Illinois, 362 Noyes Lab. of Chem., Urbana, Illinois.

Technical Societies Cooperation with Chemical Engineering Industries

CHAIRMAN: Prof. J. B. Phillips, Dept. Chem. Eng., Phys. Sciences Centre, McGill Univ., Montreal 2, Canada.

Mechanics of Bubbles and Drops

CHAIRMAN: Prof. R. C. Kintner, Dept. Chem. Eng., Ill. Inst. of Tech., 3300 Federal St., Chicago 16, Ill.

Deadline—July 27, 1955

■ **LOS ANGELES, CALIF.**

Feb. 26-29, 1956. Statler Hotel.

TECHNICAL PROGRAM CHAIRMAN: T. Weaver, Proc. Eng., The Fluor Corp., Ltd., Box 7030, East L. A. Station, Los Angeles 22, Calif.

Deadline—Oct. 26, 1955

■ **NEW ORLEANS, LA.**

May 6-9, 1956

Program chairmen not announced

■ **PITTSBURGH, PA.**

Sept. 9-12, 1956

TECHNICAL PROGRAM CHAIRMAN: Carl C. Monrad, Carnegie Institute of Technology, Pittsburgh, Pa.

■ **ANNUAL—BOSTON, MASS.**

Dec. 9-12, 1956. Hotel Statler.

TECHNICAL PROGRAM CHAIRMAN: W. C. Rousseau, Proc. & Sales Eng., Badger Mfg. Co., 230 Bent St., Cambridge 41, Mass.

Deadline—August 9, 1956

■ **WHITE SULPHUR SPRINGS, W. VA.**

Mar. 10-13, 1957

Program chairmen not announced

■ **BALTIMORE, MD.**

Sept. 15-18, 1957

Program chairmen not announced

UNSCHEDULED

Extraction of Hydrocarbons for Chemical Use from Pipeline Gases

CHAIRMAN: E. E. Frye, J. F. Pritchard & Co., 210 W. 10th, Kansas City 5, Mo.

Fundamental Mechanisms in Boiling Cavitation and Condensation

CHAIRMAN: R. R. Hughes, Shell Development Co., Emeryville, Calif.

Engineers Joint Council Nuclear Engineering and Science Congress will be held in Cleveland, Ohio, on December 12-16, 1955.

The A.I.Ch.E. tentatively plans to sponsor papers on the following: liquid metals, heat transfer, radiation, and sterilization, and chemical manufacture, preparation of radio active sources, processing of spent fuels and temperature coefficient for reactors. A.I.Ch.E. representative—Dr. W. K. Woods, Vice-Chairman, Nucl. Eng. Div., General Electric Co., Richland, Wash.

"MIGHTY MITE" SOLVES CHEMICAL PUMP PROBLEMS

The Eco All-Chem Pump is the All-Teflon and stainless steel pump that handles 70 percent of corrosive chemical requirements in Lab., pilot plant and small volume pumping in production service.

Simplify selection; standardize on fewer types, models, sizes; minimize maintenance problems.

READ THE SPECS . . . SPECIFY AND TRY

- *Type Pump:* Positive displacement with two opposed axially oscillating impellers equivalent to duplex piston operation.
- *Volume:* ½, to 10 g.p.m. maximum at 1750 RPM (water).
- *Pressures:* to 70 psi.
- *Suction Lift:* Highest over widest temperature and viscosity range.
- *Corrosion Resistance:* Lowest corrosion rate due to internal flow pattern. Handles all chemicals that stainless steel No. 316 will handle.
- *Pump Operating Characteristics:* Linear delivery. No air entrainment. Non-foaming. Unequalled for safety in handling hazardous liquids such as nitric acid and hydrogen peroxide. Self-priming on non-volatile liquids.
- *Drive:* Applicable to direct motor drive at 1750 RPM, as well as to all other standard driving methods.

All-Chem PUMPS ECO

ENGINEERING COMPANY

12 New York Avenue • Newark 1 • New Jersey

task force

at Savannah River

The tremendous industrial undertaking of the design, engineering, and construction by E. I. du Pont de Nemours & Company of the now well-known Savannah River Project, which produces vital materials for A- and H-bomb weapons, demonstrates what can be accomplished when science, business, and labor willingly join hands at government request for the defense effort. In this vein Granville M. Read, chief engineer of Du Pont, recently discussed his company's responsibility in carrying out the assignment at Savannah River. Ironing out all the details in itself was a gigantic task—delegating responsibility to the explosives department, which set up a separate division, obtaining top personnel from industrial departments, seeking services by the auxiliary departments, receiving the Executive Committee's advice on major policies, and assigning to the engineering department the onus for the design and construction, and in turn that department's subcontracting of many phases of the work.

Recalling one formidable job, namely the selection of a plant site, Mr. Read said:

"The A.E.C. and the Department of Defense had issued certain rigid criteria. The nature of the product established many unusual factors which would be absent in picking a site for an ordinary commercial operation.

". . . The site investigation dealt with all the elements and all the forces of nature. It involved: (1) climatology, covering river flows, rainfall, floods, and temperatures; (2) geology, covering underground soil foundations, water tables and underground drainage conditions, and finally the probability of an earthquake; (3) meteorology, covering wind patterns, air currents, storms, intensity of lightning, atmospheric electrical disturbances and their effect on electric power failures; (4) biology, covering plant and marine life and its propagation. Other cardinal factors included traffic, railways, highways, population surveys, telephone and other communication systems. This information, particularly the climatology and geology, was needed for the design of heavy structures, the large equipment foundations, reservoirs, powerhouses, anchor blocks, water intake and waste disposal. . . .

"The plant would eventually occupy some 200,000 acres, or about four times the size of the District of Columbia. It would have an electric power system comparable to the state of Delaware, and water consumption approximating that of Philadelphia.

"Some 114 sites were investigated, and in November, 1950, three months after the contract was let, the choice by a joint review committee was an area of South Carolina on the Savannah River, beginning 18 miles southeast of Augusta, Georgia, and 15 miles south of Aiken, S. C."

Mr. Read continued:

"Meanwhile we had set up an atomic engineering section completely divorced from commercial work. The key positions were manned by seasoned engineers who were held responsible for design, construction, engineering research and development, fabricating shops, and cost control. Their crews were expanded as the work load increased. A small group of 'sharp shooters' smoothed out the inevitable differences and reamed out the bottlenecks. . . ."

Going further into details Mr. Read stated that into one technological effort

Florex—for adsorption

Recognized throughout the world as superior to all other natural clays used in adsorption processes, Florex is particularly effective in the adsorptive refining, decolorization, clarification and neutralization of mineral, vegetable, and animal oils, fats and waxes. Florex is also effectively used for sweetening light distillates, dehydration, desulfurization and polymerization.

Florex is prepared from carefully selected natural Florida Fullers Earth by a special processing including high-pressure extrusion, which greatly improves adsorptive efficiency and capacity.

Standard particle sizes are herein reproduced and include meshes from 2/4 to 200/ up. Special meshes are also available. Florex is packaged to fulfill customer's requirements with the Fifty (50) pound non-returnable paper bag the minimum quantity.

For further information use free request coupon below.

FLOREX MESH—ACTUAL SIZE

100-UP
60/100
30/60
16/30
8/16
4/8
2/4

FLORIDIN COMPANY

• Adsorbents
• Desiccants
• Diluents

DEPT. Z, P. O. BOX 998
TALLAHASSEE, FLORIDA

Please send literature ☐ and sample ☐ of Florex
(Be sure to indicate mesh size_____)

Name_____

Address_____

City_____

some 120 different skills and talents were combined to achieve the final design. This meant drawing upon the scientific brains of Du Pont's research laboratories, upon management, supervision, and operating personnel, upon professional consultants in specific fields. "In a word we called on every resource and benefited from every policy established during the Du Pont company's background of more than a century and a half of industrial growth. This was perhaps the company's greatest contribution to the Savannah River Project."

Referring specifically to the engineer's part in the project, chief engineer Read said the engineer's job, in a project of this magnitude, is to be the interpreter, to translate basic scientific knowledge into reliable, operatable equipment, and into general plant facilities which can be controlled and maintained by the average trained operator. He continued:

"Our difficulties in interpretation were multiplied many fold because most materials of construction would be exposed to the new hazard of radiation. In addition to its normal properties, equipment had to be selected on the basis of what physical change would take place when it was subjected to various degrees of radiation. Abnormal and unprecedented corrosion and wear condition had to be anticipated. We had to allow for changes in fiber stress in certain metals. . . ."

The word automation—the word of the hour—was not overlooked in Mr. Read's speech. He stated that, though normally it is thought of as a series of continuous, mechanical operations, when alluding to Savannah River it is necessary to go a step further. In other words, the newest electronic techniques known were incorporated to monitor and control each phase of the operation, he claimed.

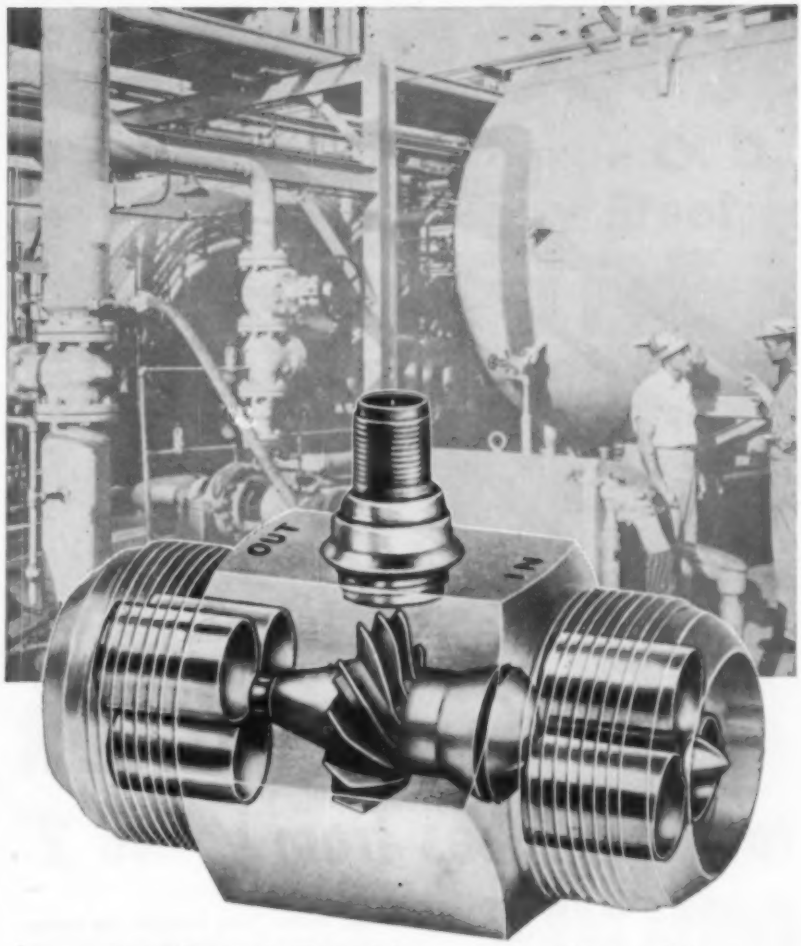
On this point Mr. Read clarified the situation at Savannah River by explaining in this wise:

". . . the tremendous potential energy locked up in the atom must be released gradually. This requires controls so sensitive that human operation would be practically impossible. The pulse of the reaction must be taken continuously. The speed of electronic controls is imperative to do this, and also to automatically set in motion the nuclear corrective measures required to compensate for the slightest change. . . .

"Mechanical precision and remote controls in certain parts of these processes are the key to their successful operation. Some of the equipment pieces weigh as much as 250,000 pounds, yet the tolerance requirements were as rigid as those of a watchmaker. . . .

"In the design of Savannah River, therefore, all known phases of today's

(*Continued on page* 84)



Potter Electronic Flow Meters measure acids, caustics, suspensions at high or low temperatures and pressures with great accuracy!

if the question is flow
the answer is Potter

● Potter Electronic Sensing Element with turbine-type "floating rotor" generates current whose frequency is directly proportional to flow rate. Inherently linear element has extremely wide rangeability, low pressure drop.

New Potter Electronic Flow Meters are used for accurate, foolproof, continuous measurement and control of hard-to-handle liquids with an accuracy of ± ½% of true flow over the recommended range. Supplying information in terms of weight or volume, they are efficient at temperatures from —450 to 1200°F and under pressures as great as 35,000 psi. Further advantages are swift, economical installation, low maintenance.

There are complete Potter Flow Meter Systems, including Recorders, Indicators and Digital Totalizers to meet your specific needs.

Write for Bulletin LS-1

Potter **POTTER AERONAUTICAL COMPANY**
Route 22 • Union, New Jersey • Phone MUrdock 6-3010
makers of Potter engineered products

Here's POWER to clean tubes from 1/2" to 2" QUICKLY

Rotojet Junior Tube Cleaners are unusually powerful for their size and weight. They are fed easily through the tubes with the operating hose, and can be shifted quickly from tube to tube. Their convenient size, speed, and ease of operation offer a marked contrast with external cleaners costing many times more.

An air valve directly behind the Rotojet motor permits one-man operation. Very little headroom is required, and either vertical or horizontal tubes can be cleaned.

Simplicity of Rotojet design and precision construction assure long service, efficient use of power, and freedom from trouble. Economical brushes, cutters, and scrapers meet practically any requirement.

Send for Bulletin J-410.

Expanding scraper and replaceable element.

Expanding brush and replaceable element.

Sectional wire brush.

Air valve for one-man operation.

ROTOJET®
Junior TUBE CLEANERS

ELLIOTT COMPANY-ROTO DIVISION

149 Sussex Avenue • Newark, N. J.

TASK FORCE

(*Continued from page* 83)

technology were used, and I might add for the record, we came up with a few which did not previously exit. . . ."

The speaker then added a few interesting details.

"Construction activity started in earnest in February, 1951, less than three months after selection of the site. It increased steadily until our force reached a peak of some 38,500 employees in September, 1952. The average age of our supervisory group was about 40 years and upwards of 5,000 were technically trained employees.

"To mobilize quickly so large a construction team required that top personnel be pulled from Du Pont's commercial plants to fill key spots. . . .

"We have worked more than 172 million man-hours. Less than one-half of one per cent of the total hours worked were lost as a result of labor disputes. . . .

"It is estimated that the ultimate cost of the project will be around one billion, three hundred million dollars in government funds. . . ."

Deviating somewhat from the story of the Project and its technical details, Mr. Read alluded to a cost reduction program at Savannah River in line with a policy with his company. "Twice yearly," he said, "we established cost reduction objectives, and broke down the over-all goals into departments, areas, and craft. The prime objective was to have all elements of design and construction analyzed for the possibility of eliminating waste.

"One of the most interesting features of this program is the employee suggestion system." He said that "more than 55,000 suggestions have been received, most of them directed toward reducing construction expenditures. The employees received awards ranging from $15 to $500 for each suggestion adopted. This relatively modest award money provided an incentive for the employee. To date we have saved millions of dollars from all the items going into our formal economy program, and every item is recorded. . . ."

Concluding, Mr. Read said in part: "I think you will agree that it took the combined efforts of big business and little business, of labor and management, brought together by fusion in one homogeneous team, to accomplish this vast undertaking which harnesses the energy of the atom. . . ."

These remarks are digested from a speech given by G. M. Read, chief engineer, E. I. du Pont de Nemours & Company, before the Rotary Club in Wilmington, Delaware.

News of the Field
FROM LOCAL SECTIONS

St. Louis, Missouri. An escape from earth by overcoming the gravitational forces of the earth was presented as a possibility by P. W. Godfrey, Thermodynamic Engineer, Missile Engineering Division, McDonnel Aircraft Co., to the December 14 meeting of the St. Louis Section. Mr. Godfrey described recent developments in the rocket and showed slides of German films of the V-2 and a film of the operation and launching of a version of the V-2 at White Sands Proving Ground. He reviewed various aspects of rocket theory and design as well as future applications of solid and liquid propellant rocket power plants.

"The rocket has not reached the state of being entirely reliable," said Mr. Godfrey, "but then neither has the automobile." The rocket does fill a position of being practical, but only for particular applications. These applications seem to be limited to cases where large forces are desired for relative short periods of time or where the lack of oxygen and pressure prevent the operation of economical (fuel wise) power plants such as the turbo jet or ram jet, or where large amounts of energy are desired but in a midget size package.

The combined talents of almost every field of engineering are required to solve problems associated with the extremes of fluid flow, heat transfer, mechanical design, and combustion.

—A. Rose

Chicago, Illinois. Another reminder to "good citizens," who have shown indifference as to whether or not their city governments are good or bad, to actively follow politics and to concern themselves with the management of their municipalities was brought to the January meeting of the Chicago Section by Alderman Robert E. Merriam of Chicago, a candidate for the Mayoralty. Mr. Merriam in his talk "Big City Politics" emphasized the importance of local governments. He considered good government the responsibility of every citizen and repeatedly stressed this point by citing numerous examples of bad government in Chicago and other large cities.

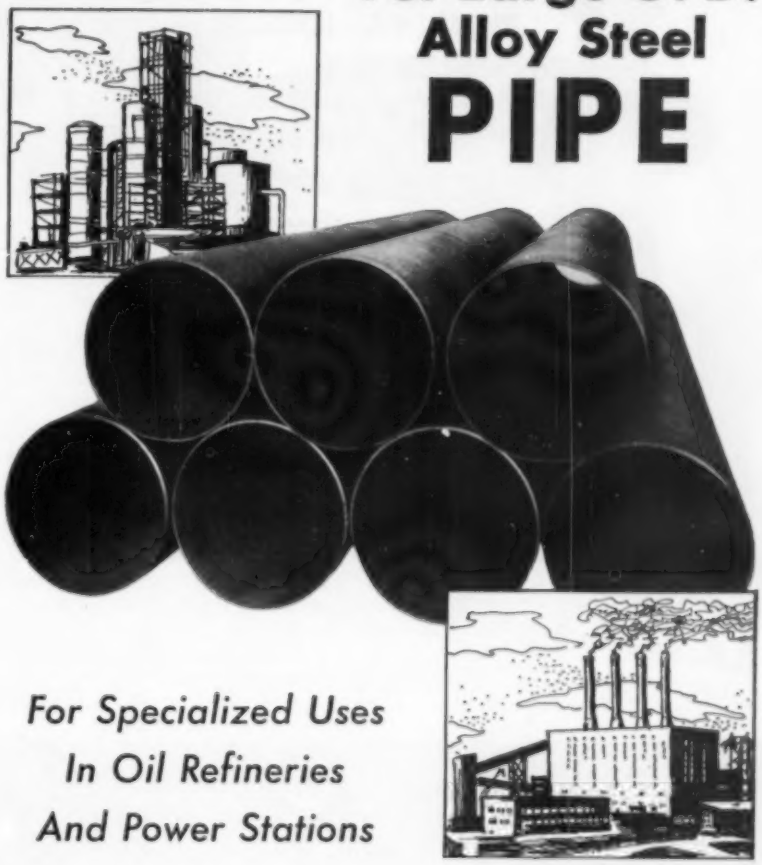
—S. G. Sourelis

Dallas, Texas. At the December 14 meeting of the Dallas Section the following were elected officers for 1955: Chairman, W. Swerdloff; Vice-Chairman, J. Rush; Secretary-Treasurer, C. Holland; Executive Committee, O. Kimbler, R. Jenkins, J. Richardson.

—H. A. Blum

See POSEY

For Large O. D. Alloy Steel PIPE



For Specialized Uses In Oil Refineries And Power Stations

You can depend on Posey to meet your requirements in large O. D. alloy steel pipe . . . and you can depend on Posey to turn out your job economically and on time.

- *Posey Alloy Steel Pipe is fabricated in accordance with ASTM specifications, Class A 155-52 aT.*
- *Posey specializes in large O. D. Pipe and Pilings of low and high alloy steel, alloy clad steel, carbon steel, and wrought iron.*

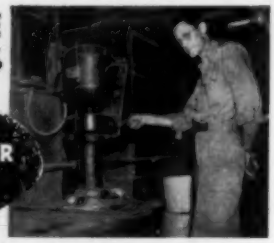
ELEVATED TANKS • HORIZONTAL TANKS • STACKS
PRESSURE VESSELS • DIGESTERS
CARBON STEEL AND ALLOY STEEL PLATE FABRICATION

POSEY IRON WORKS, INC.
Steel Plate Division
LANCASTER, PA.
New York Office Graybar Bldg. Established Since 1910

BIG PUMPING JOBS

OR LITTLE PUMPING JOBS

IF IT'S ROUGH AND TOUGH IT'S A JOB FOR *Nagle* PUMPS



Nagle Pumps are engineered and constructed with only one thing in mind . . . abusive applications. If you pump materials that eat away or grind away ordinary pumps then you need Nagles. Vertical and horizontal shaft centrifugal pumps in a complete range of sizes and capacities.

A 4" Nagle type "SW-OB" chemical pump is shown at left and a 1½" type "SW-OB" is shown at right made for a porcelain enameling firm. Both have given satisfactory performance many years . . . with many years to go.

The type "SW-OB" is submerged in material to be pumped. No stuffing box . . . no submerged bearings. Quick slippage seal adjustment. Proper materials of construction. Send for Catalog 5206.

NAGLE PUMPS

NAGLE PUMPS, INC.

1255 CENTER AVENUE, CHICAGO HEIGHTS, ILLINOIS

PUMPS FOR ABRASIVE AND CORROSIVE APPLICATIONS

SPRACO NOZZLES

Write for NOZZLE CATALOG *to*

SPRAY ENGINEERING CO.

132 CENTRAL STREET • SOMERVILLE 45, MASS.

News of the Field

FROM LOCAL SECTIONS

Western Massachusetts. It is impossible to predict what a metal will do under high pressures according to Dr. P. W. Bridgman, professor emeritus of Harvard University and 1946 Nobel Prize winner in Physics. In his talk "Some Recent Results in High Pressure Physics" before the December 7 meeting of the Western Massachusetts Section, he said that metals may act normally at 10,000 atmospheres and then completely change their characteristics at 100,000 atmospheres, with a third change possible at higher pressures.

Recent work by Dr. Bridgman at pressures of 100,000 atmospheres has been with rare metals, due to their increased sensitivity to pressure effects. At these high pressures some metals undergo electron displacement from one electron ring to another while other metals undergo polymorphic changes from body cubic lattice structure to face centered cubic crystal cells.

Electrical resistance measurements have made available much data on these structural changes in metals but no theory has yet been advanced to support the experiment data. Dr. Bridgman said that with such unpredictable behaviour the day of the smooth curve explaining performance is passed.

He gave a description of apparatus used for his work at pressures beyond the crushing strengths of most metals in which he utilizes friction to keep his test cell from blowing up.

—R. T. Bogan

Atlanta, Georgia. The minerals in Georgia were described by A. S. Furcron, Asst. State Geologist, to a December 8 meeting of the Atlanta Section. In describing the geological formation and composition of that area, Dr. Furcron aroused the urge to prospect in many of the twenty-nine members present.

An election of officers for 1955 was held. They are: Chairman, J. J. Wimberly; Vice-Chairman, H. H. Sineath; Secretary-treasurer, F. E. Rowe; Executive Committee, P. Weber, N. R. Maleady; E. M. Jones, R. C. Barrett.

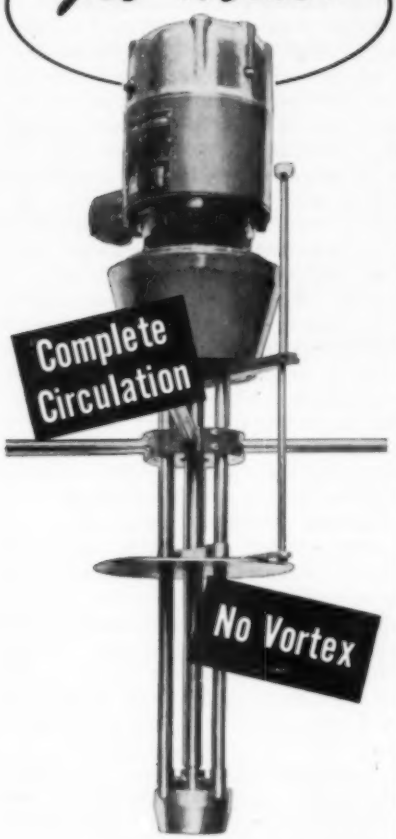
—H. H. Sineath

Orange, Texas. The various types of stream pollution and the affects of each upon aquatic life was told to a December 15 meeting of the Sabine Area Section by R. Patrick, Philadelphia Academy of Natural Sciences. In her talk on "Aquatic Surveys for Determining River Health" Dr. Patrick commented on personal surveys in local waters. Color slides were presented supplementing the talk.

—W. E. Norris

HERMAS

Jet Mixer



MIXES IMMISCIBLE LIQUIDS

All material in mixing container is drawn into mixing chamber where it is immediately disintegrated homogeneously, compressed through outlet jets, and discharged with high kinetic energy.

This continual recirculation of material, aided by pumping action of the pitched turbine blades, is rapidly repeated until all material is uniformly treated.

For full description of mixer write for four-page illustrated folder giving explanation of principle of operation, mixer sizes, working capacities, typical applications, and other helpful data.

HERMAS

MACHINE COMPANY

Warburton Ave., Hawthorne, N. J.

A.I.Ch.E.

News of the Field

FROM LOCAL SECTIONS

Baltimore, Maryland. How do fluids in the microscopic pores of rocks move—such as would be encountered in the production of petroleum from oil bearing sandstone. A film "Fluid Distributions in Porous Systems" showing time-lapse micromotion pictures of fluids impregnated in a model of sandstone rock core was presented to the December meeting of the Maryland Section. The film, made by the Stanolind Oil and Gas Company of Tulsa, Oklahoma, has been made as part of a research project which is investigating fluid distribution in rock pores while certain flow processes take place.

At this meeting the following officers were elected for 1955: Chairman, L. C. Palmer; Vice-Chairman, T. O. Tongue; Secretary, J. G. Hough; Treasurer, W. H. Weed; Executive Committee, A. W. Taft, L. E. Herbert, and E. L. Knoedler.

—A. T. OSSERMANN

Rochester, New York. The energy equivalent of two nominal atom bombs per day per square mile are received on the earth from the sun according to H. C. Hottel, Professor of Fuel Technology at M.I.T., talking before the January 12 meeting of the Rochester Section on the "Utilization of Solar Energy." Mr. Hottel said that although this is a very large quantity of energy, it comes to us in a very dilute form. Presently, domestic heating is probably the only application for solar energy which appears attractive.

—J. A. MASON

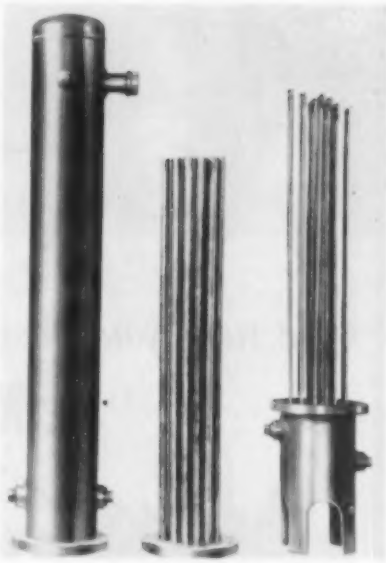
Southern California. Two experts from C. F. Braun & Co. discussed heat transfer and heater design at the December 14 meeting of the Southern California Section. L. Scheppe, in discussing radiant heat transfer and factors affecting firebox design, described the effect of tube-to-wall clearance on heat distributions and the influence of excess air on efficiency. The new process, new materials and the economics behind the new look, acquired by fired-heaters in recent years, were described by L. B. Sutherland.

—F. G. SAWYER

Texas Panhandle. An announcement of the officers for the Panhandle Section was made at a recent meeting. They are: Chairman, E. H. Gray; Vice-Chairman, H. R. Harris; Secretary, B. Rushford; Treasurer, S. A. Blundell; Directors, A. R. Crandall, C. M. Kron, and H. W. Weaver.

—H. R. HARRIS

VAPORIZERS
AMMONIA CHLORINE
PROPANE



720 lb./hr. ammonia vaporizer disassembled, illustrating easy access for repair, cleaning or inspection with minimum effort.

STANDARD DESIGNS
VERTICAL AND HORIZONTAL
for prompt shipment

CAPACITY RANGES:

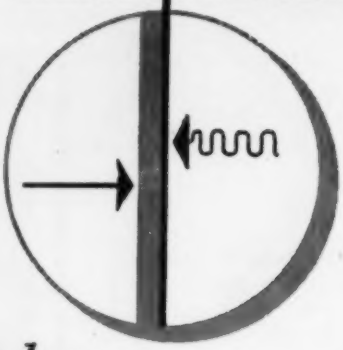
AMMONIA	60—14,000 lb./hr.
CHLORINE	180—49,000 lb./hr.
SO_2	150—42,000 lb./hr.
PROPANE	40—10,000 gal./hr.

ASME STAMPED
NON-FREEZE DESIGN

Richard M. Armstrong Company
Box 188
West Chester, Penna.

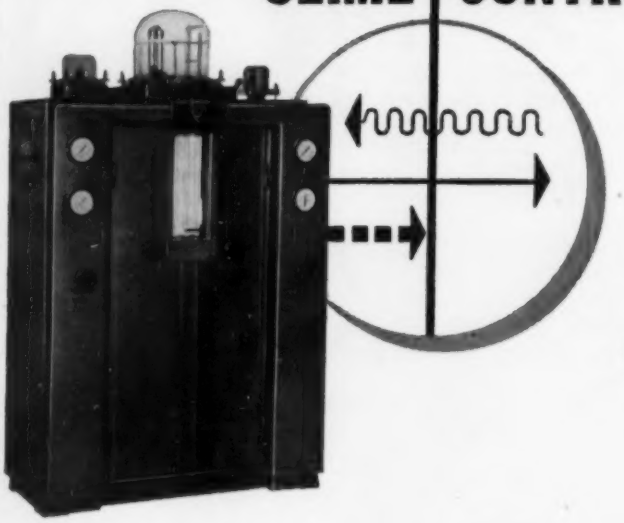
Where you need

HEAT | EXCHANGE



Be sure you have

SLIME | CONTROL



Whether you heat or cool water for make-up, process or any other use, you will need Wallace & Tiernan Chlorination to help combat slime problems introduced by water-borne bacteria or air-borne bacteria.

With slime control equipment designed for any need, built for lasting and dependable service, highly accurate and backed by over 40 years of successful application experience, Wallace & Tiernan Chlorination can help you increase the efficiency of your plant and cut operating costs. For further information write our Industrial Division.

WALLACE & TIERNAN

25 MAIN ST., BELLEVILLE 9, N. J.

CHLORINATORS • CHEMICAL FEEDERS • SCREENING EQUIPMENT • MAGNETIC SEPARATORS • PRECISION PRESSURE INSTRUMENTS • CATHODIC PROTECTION • FINE CHEMICALS

CD-39

News of the Field

FROM LOCAL SECTIONS

Pittsburgh, Pa. The Pittsburgh A.I.Ch.E. Student Award sponsored by the Pittsburgh Section will be given for the first time this spring. The award is for the best written report on laboratory experiments in Unit Operations performed by chemical engineering students in their senior year or, in some cases where the course is presented only in the junior year, those reports completed in the second semester. Two award winners will be selected and will be presented $20 in technical books and a year's subscription to CHEMICAL ENGINEERING PROGRESS. Awards will be presented on March 3, 1955 at the student night meeting of the Pittsburgh Section.

Each school may enter two contestants and each contestant is to submit two laboratory reports previously submitted to a professor while taking the course. A fair copy of the reports as finally accepted by the instructor is permissable for submission and the student may recopy any material in his original submission and may redraw any charts. The award selection will be made more on the clarity of writing and the excellence of presentation rather than on physical appearance.

Organization, accuracy, conciseness and clarity, grammar, appearance, and effectiveness are the six points by which each report will be evaluated.

—H. B. Coats

Bartlesville, Oklahoma. New officers for the Oklahoma section for 1955 are: Chairman, H. B. Irvin; Vice-Chairman, L. W. Pollock; Secretary, E. W. Mellow; Treasurer, E. R. Beck; Executive Committee, M. F. Wirges, J. E. Cottle, H. R. Legatski.

—J. J. Moon

New York, New York. How to direct the imagination so that it may lead to the invention of new consumer products was described to a January 19 meeting of the New York Section by Hazel Bishop, renowned cosmetic formulator.

l. to r. R. F. Shaffer, Hazel Bishop, A. B. Babcock.

Miss Bishop said that if your idea really answers a public need you can expand that idea into big business—if, however, you are willing to boldly take the initiative and sacrifice some of your security. To illustrate this she cited the growth of Hazel Bishop, Inc. which grew from an idea into a $10,000,000/year business in a few short years.

Along with a sound technical background and clear observation the inventor of consumer products must project himself into the role of the consumer. He must learn to evaluate products as does the consumer. The general public as such seldom initiates a new idea. As a result, surveys of public opinion have little value in the creation of a new idea; however, they are necessary in determining public acceptance of a new product. Miss Bishop cautioned that there is futility in attempting to violate fashion.

There would probably be many more new and useful consumer products on the market if those with good ideas were to set aside their attention to achieving security and gamble a bit on new enterprises.

St. Louis, Missouri. How to evaluate and finance a new chemical plant was told to the St. Louis Section at their November 16 meeting. K. Finsterbusch, Vice-President of Stone & Webster Engineering Corp., N. Y., in his talk on "Plant Evaluation and Financing," described the broad aspects of planning

"Old timers" in St. Louis.

and construction of chemical plants, gas pipe lines, power plants and many others. This meeting marked the "Old Timers Night" which each year honors its founders, leading engineers and executives of the chemical industry, consultants and university instructors, and those who have been associated with its activities over the years.

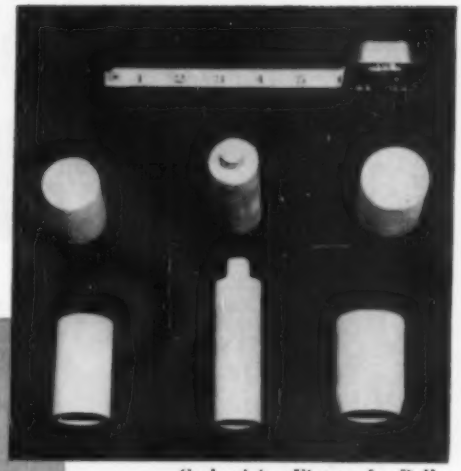
—W. Rodgers

Summit, New Jersey. Substantial amounts of raw aromatic organic chemicals will in the near future be derived from the

(*Continued on page 92*)

Small

HIGH ALLOY CASTINGS

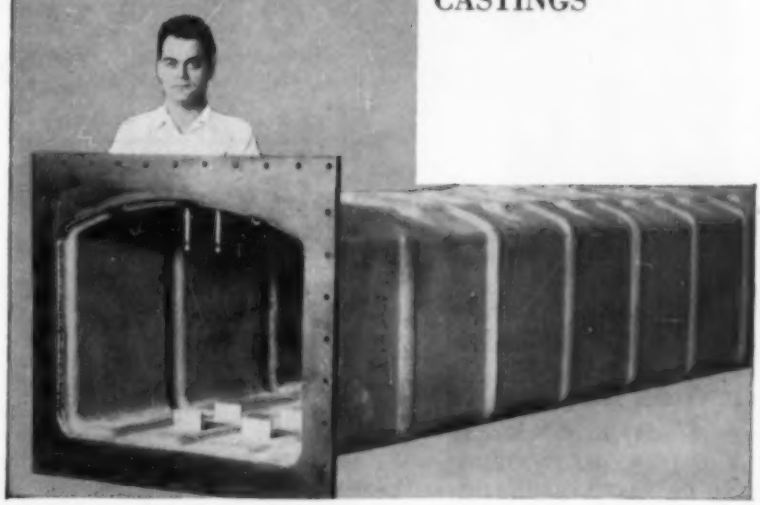


Carburizing Fixture for Ball Bearings 1½" diameter—Analysis 35% Ni — 15% Cr

DURALOY

Large

HIGH ALLOY CASTINGS



Muffle for Continuous Strip Annealing 12' 6" long — Analysis 38% Ni — 18% Cr.

LARGE or small DURALOY, can do it! These are just typical examples of the work moving through our foundry. Some of these castings are designed for heat resistance, some for corrosion resistance, some for abrasion resistance; all are cast by experienced foundrymen. All are carefully tested in our up-to-date laboratory.

If you have a high alloy casting problem . . . LARGE or small, we can help you. For more information, send for Bulletin No. 3150-G.

THE DURALOY COMPANY

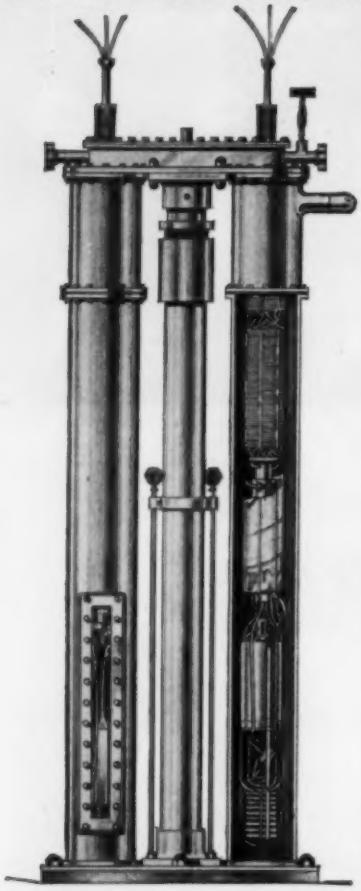
Office and Plant: Scottdale, Pa. • Eastern Office: 12 East 41st Street, New York 17, N.Y.

Detroit Office: 23906 Woodward Avenue • Pleasant Ridge, Mich.

Atlanta: J. M. TULL Metal & Supply Co. Chicago: F. O. NELSON 332 S. Michigan Avenue

METAL GOODS CORP.: Dallas • Denver • Houston • Kansas City • New Orleans • St. Louis • Tulsa

HERRICK L. JOHNSTON, INC.



FOREMOST DESIGNERS OF LIQUEFIERS

30 years experience in Low Temperature Research and Engineering

MANUFACTURER OF LABORATORY AND INDUSTRIAL PLANTS*

Designs for the production of liquefied gases

HELIUM • HYDROGEN

OXYGEN • AIR • NITROGEN

*Portable or Stationary Installation

Production Capacity—all plants constructed to meet your requirements. Present plants for liquid helium and hydrogen include ranges from 10-1000 liters of liquid per hour.

VACUUM-JACKETED STORAGE AND TRANSPORT VESSELS — ALL SIZES

Vacuum-jacketed Transfer Lines for Handling Liquefied Gases

Designed for:

- **Minimum evaporation losses**
- **Low Maintenance**
- **Ease of operation**

YOUR INQUIRIES ARE INVITED

ADDRESS:

HERRICK L. JOHNSTON INC.
GENERAL OFFICES
540 W. POPLAR AVE.
COLUMBUS 8, OHIO

Brooklyn Polytech one-day symposium

I. to r.—Author group: R. W. Krebs, R. M. Braca, D. F. Othmer (Chairman), E. J. Gohr, W. W. Kraft, F. A. Zenz, Clyde Berg, and R. B. Thompson.

The recounting of experiences in the design and operation of plants utilizing fluidized solids by leading engineers who have been pioneers in this field was carried on in a symposium "Fluidization in Practice" at the Brooklyn Polytechnic Institute on February 2. The meeting was sponsored by the Chemical Engineering Department under the chairmanship of D. F. Othmer and was held in cooperation with the New York and New Jersey Sections of the A.I.Ch.E.

The meeting was opened by Harry S. Rogers, president of B.P.I., who defined this function as part of its centennial year celebration, which calls attention to the contributions of engineering, science and research to human well-being. F. J. Van Antwerpen, secretary of A.I.Ch.E., cited the early close relationship of B.P.I. and the A.I.Ch.E. through John C. Olsen, former head of the Department of Chemical Engineering at Brooklyn and first secretary of A.I.Ch.E.

Seven papers were presented, in which were discussed the applications of fluidization to the design of processes and equipment, the operation of plants and their problems, materials of construction as affected by corrosion and mechanisms for the transport of solids and fluids.

Like so many other chemical engineering developments, the fluidized solids technique was extensively applied before being thoroughly understood, ac-

CHEMICALS TO CORNFIELDS

(*Continued from page 79*)

solutions" which are more convenient and economical for mixed fertilizer manufacture. Tuscola produces several grades to enable shipment and use of highest nitrgen-content ammonium nitrate solutions capable of withstanding freezing under anticipated weather conditions. In other words, the dissolved ammonia acts as a freezing point depressant. In the table below, USI type No. 1, which contains 65% NH_4NO_3, freezes at 23° F. even though it has 21.7% free ammonia content. This would obviously be a hot weather composition, while type 2 would be shipped under colder weather conditions. Higher ammonia contents than needed to prevent freezing bring on elevated vapor pressure problems in transportation, storage, and use.

Ammonium nitrate is made by combustion of ammonia with air over a platinum catalyst, with absorption of resulting oxides in water. Ammoniation of the solution first produces ammonium nitrate through neutralization, and is continued until the desired composition of "nitrogen solution" is reached. Both nitric acid and solutions plant units were designed and constructed by The Chemical & Industrial Corporation, Cincinnati, O.

Credit and thanks for information are due Lawrence C. Byck, Jr., acid and nitrogen products manager, and David J. Patterson, USI plants (Tuscola) manager U. S. Industrial Chemicals Co., a division of National Distillers Products Corporation.

Nitrogen Solution Formulations

USI type No.	% total nitrogen	% ammonium nitrate	% ammonia	freezing pt. ° F.	vapor pressure, lb./sq.in. @ 100° F.
1	40.6	65.0	21.7	23	8
2	40.8	55.5	26.0	—13	14
3	37	66.8	16.6	48	2
4	49	60.0	34.0	—49	46
5	53	36.0	49.0	—73	104

Equivalent designations: *USI type 1*—Spensol A (Spencer), Nitrana 2-A (Nitrogen Div., Allied), Dixsol 101 (Commercial Solvents); *USI type 2*—Spensol B, Nitrana 3, Dixsol 102; *USI type 3*—Spensol C, Nitrana 4, Dixsol 103; *USI type 4*—Spensol D, Nitrana 6; *USI type 5*—Spensol U.

The above table lists only a portion of the commercial suppliers of nitrogen solutions having properties similar to those made at Tuscola. Purpose is to indicate standardization.

cording to E. J. Gohr, of Standard Oil Development Co., in discussing the history and future of fluidization. The technique was described as applicable to processes involving very severe operating conditions such as high temperature and pressure. It is potentially applicable to any process in which large quantities of heat are transferred between finely divided solids and gases, large quantities of solids must be circulated, or very intimate contact between gases and solids is desired.

Erosion by fluidized particles has contributed to more time-consuming shutdowns than any other operating factor in fluidization installations according to R. M. Braca and A. A. Fried, Foster Wheeler Corporation. In the design of equipment such factors as shape of vessels and the meshed reinforcement of internal linings with hard dense materials should be carefully considered. Early gas-distribution plates permitted formation of "bubbles." A grid design employing an upwardly-concave dished perforated plate efficiently minimizes this.

The Fluid Coking process was described by R. W. Krebs, Esso Laboratories, Baton Rouge. The complete conversion of the heavy tarry still bottoms of petroleum refining into useful products has been accomplished with this process. Coke by-product resembles fine black sand and can be burned as powdered fuel, making it a promising raw material for chemical and metallurgical processes.

Some of the more recent design and control techniques for solids conveyance, flow control and level control were reviewed by C. Berg, Union Oil Company of California. The hyperflow process, one of the newest methods for solids transfer, was described as advantageous in permitting the elimination of sealing legs, compactness, and reduced investment costs.

A graphical method for analysis of the physical conditions describing fluidization was presented by F. A. Zenz, M. W. Kellogg Company. A generalized fluid-solids flow diagram has served as a working tool in making flow and pressure balances in a manner similar to the enthalpy charts in heat balance. Not new mathematically, it offers a simple method for making calculations.

Details of design, instrumentation and operating control were analyzed by Wheaton Kraft, of The Lummus Company, with reference to fluid catalytic cracking unit experience.

The design of feeding and discharging mechanisms of fluid type bed reactors was considered by R. B. Thompson of Dorr-Oliver, who outlined methods in handling ores.

*FIRST LINE

Extended-Surface

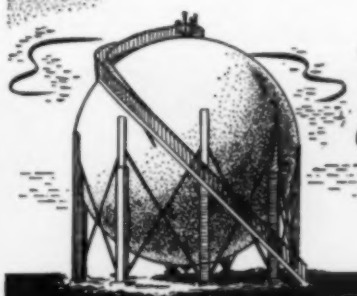
HEAT EXCHANGERS

ASK THE AEROFIN MAN

Specify Aerofin and you specify high efficiency, long service life and low maintenance and service costs.

Take advantage of Aerofin's unequalled experience, production facilities, and materials-testing and design research — of Aerofin's complete engineering service at the plant and in the field.

* *Aerofin makes extended heat surface exclusively — not as a by-product, not as a side-line.*



Throughout the Chemical Industry —

Aerofin units do the job Better, Faster, Cheaper

AEROFIN CORPORATION 101 Greenway Ave. Syracuse 1, N. Y.

Aerofin is sold only by manufacturers of fan-system apparatus. List on request.

Processing equipment you need

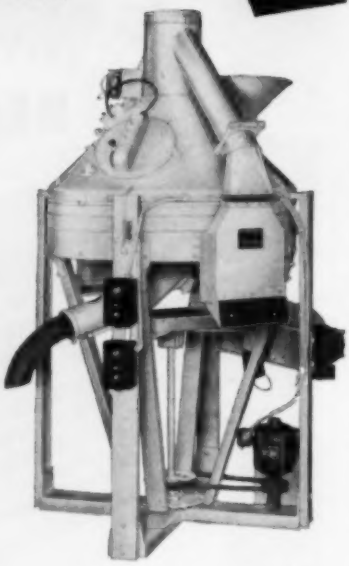
for crushing, grinding, granulating, pulverizing, texturizing, fiberizing, separating, classifying

Many of your processing problems can be readily solved by looking over our literature on the extensive line of Bauer equipment. If you get up to the point where you want specific information, we'll be glad to give you the benefit of our long experience in the processing field.

What's more, we have two research laboratories in which we can make tests and short production runs if we don't already know the answers to your problems.

Our line consists of breakers, crushers, attrition mills, laboratory mills, granulators, texturizers, fiberizers, cleaners, separators, exhausters—all briefly described in Bulletin No. 52.

Ask for the bulletin. No representative will call unless invited.



THE BAUER BROS. CO.
1794 Sheridan Ave. • Springfield, Ohio
Established 1879

Bauer Specific Gravity Separator which cleans or classifies many products and materials by a combination of mechanical and pneumatic forces.

If MIXING is the problem . .

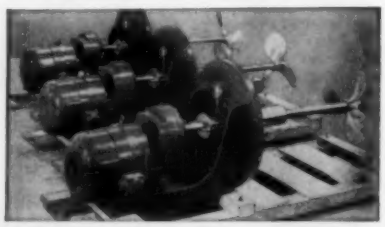
ALSOP has the answer

If your process involves mixing, blending, suspending or dissolving it will pay you to invest in an Alsop Mixer that can mean big savings in your processing costs.

Alsop portable Mixers, in sizes from 1/20 H. P. to 7 1/2 H. P. with easy-to-mount, quickly adjustable clamp makes small batch mixing simple and economical and you'll find it easy to attach to any open container.

Write for complete information giving details and quantities to be handled.

Alsop offers a complete and full line of stationary Mixers and Agitators with a wide range of powers, speeds and propeller combinations to choose from.



ALSOP ENGINEERING CORPORATION
1002 Gold Street Milldale, Conn.

It pays to buy - **ALSOP**
FILTERS - MIXERS - PUMPS & TANKS

(Continued from page 89)

coal hydrogenation process. R. Gorman, Carbide & Carbon Chemical Co., in a January talk before the New Jersey Section, said that the expected demand for these organic chemicals over the next 20 years will require additional sources of raw materials. One means of helping to meet this demand is the coal hydrogenation process which is being developed in pilot plant operations in Charleston, W. Va. In discussing some of the economics of the process Mr. Gorman said that a remote controlled mining machine will be a factor in reducing the cost of coal, the basic raw material.

The coal-hydrogenation process which has been under investigation by Carbide for the past 20 years is proving to be economical for aromatic chemical production. It is presently expected that chemicals produced in the pilot plant will not compete cost wise with other sources. However, it is anticipated that a future full-scale operation will supplement coke-oven produced chemicals at competitive prices.

Process conditions have been developed to the point that more efficient production of a desired group of chemicals can be effected by proper process regulation. In contrast to the by-product method, coal hydrogenation gives much more nearly complete conversion of the raw material—coal.

Within 5 to 10 years, depending on economic conditions, this type of process might be scaled up from the $11 million pilot plant to a large scale operation. If it were required due to a national emergency, it was felt that present knowledge would permit an almost immediate scale-up. Presently, materials produced are being sold to industrial groups as well as being used by Carbide & Carbon as raw materials for other chemical manufacturing.

When questioned about the remote control coal-mining machine, Mr. Gorman said that this has been tested and has proven to be a considerable asset in the mining of coal and in lowering the cost of coal at the mine. In contrast to the approximate 10 tons/man shift obtained by present mining methods, Carbid's machine can produce 50 to 75 tons/man shift. It has cut the price of mining coal by ⅓ to ½. Although coal mined by this machine has not yet been used in the process, the reduced cost of coal produced in this way adds to the attractiveness of coal hydrogenation for chemical production as a business undertaking.

the chemical engineer in marketing

Robert B. Scrimgeour will supervise the newly established sales office of the Pfaudler Company in Kansas City.

Mr. Scrimgeour has been chemical sales engineer for the Pfaudler Co., chemical engineer at Cowles Chemical Co. and sales engineer with the Dorr Co. He was graduated in 1940 from Drexel Institute of Technology with a degree in chemical engineering.

Donald S. Black joins the sales service section in the Chemical Division of the Goodyear Tire & Rubber Company where he will handle expanding technical sales service on rubber reinforcing resins and the Chemigum rubbers.

Carbide & Carbon Chemicals Company announced the appointment of **Dr. R. L. Bateman** to the newly created position of director of product development to work with John A. Field, vice-president in charge of sales development and related activities.

Assisting Dr. Bateman in the development of markets for Carbide's newer products are **W. A. Woodcock,** new manager of the fine chemicals division and **Dr. R. H. Wellman,** new manager of the agricultural chemicals division.

James J. Hanratty has been appointed to manage the new Texas district office of Graver Water Conditioning Co.

Mr. Hanratty is a graduate chemical engineer and holds a degree also in business administration.

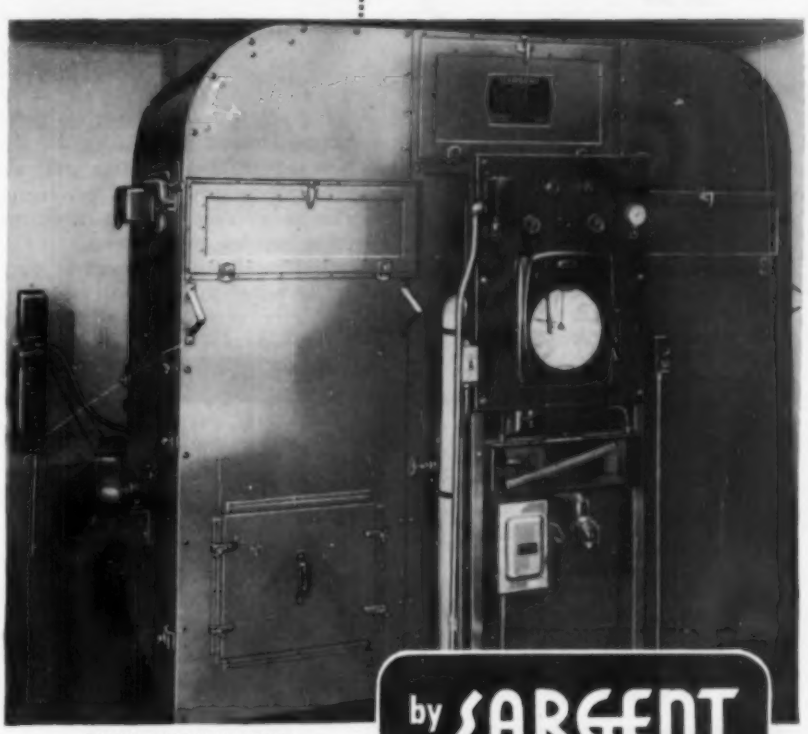
In his new position of general sales manager, **Travis V. Rankin** is in charge of sales of all Nopco Products in the Pacific division of the company. Mr. Rankin's appointment was recently announced by the Nopco Chemical Company.

J. Ross Kemmerley has taken over responsibilities of sales manager of Glascote Products, Inc.

John W. Stevens will head the expanded New York sales department of the chemical division of Celanese Corp. of America as general sales manager. **R. J. Werner** joins in the administration of this office in the newly-created capacity of assistant general sales manager.

for
PILOT PLANTS
LABORATORIES
SCHOOLS

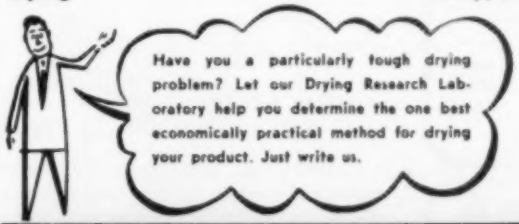
A NEW
JUNIOR SIZE*
DRYER



by SARGENT

ONLY 8'-10½" LONG,
7'-6" WIDE, 7'-1" HIGH

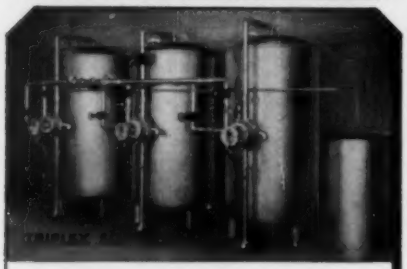
Selective recirculating air flow — updraft, downdraft or cross convection
Uses warm air, steam, natural gas fuel, or electricity
Two sample trays provided, for very small-lot testing
Main chamber for pole, tray or apron drying
Fan speeds 180 to 1800 RPM
Air velocity 0 to plus 1,000 FPM
Complete instrumentation for controlling and recording every phase of drying cycle
Once determined, entire process is transferred to regular production line easily, exactly


Have you a particularly tough drying problem? Let our Drying Research Laboratory help you determine the one best economically practical method for drying your product. Just write us.

*Modeled on the SARGENT—designed Dryer used in our own Industrial Drying Research Laboratory

C. G. SARGENT'S SONS CORPORATION
INDUSTRIAL DRYERS DIVISION
Graniteville, SINCE 1852 Massachusetts
REPRESENTATIVES: F. E. WASSON, 519 Murdock Rd., Philadelphia 19, Pa.
A. L. MERRIFIELD, 215 Grove Ave., Cincinnati 15, Ohio
W. S. ANDERSON, Carolina Specialty Co., Charlotte, N. C.
HUGH WILLIAMS & CO., 47 Colborne St., Toronto 1, Canada

ILLCO-WAY
ionXchange



HOW TO GET GOOD
SOFT WATER
OFTEN CALLS FOR
EXPERIENCED
ENGINEERING

With the advent of modern ion-exchange resins about 20 years ago, the familiar problem of softening "hard" water has found a number of new and interesting solutions. For one thing, the new resins have many times the capacity of the old greensands and zeolites. (Simply putting one of the new ILLCO-WAY Resins in your *old* softener may show a surprising saving.) For another thing, up-to-date knowledge of the available resins, and how best to use them, can lead to some interesting improvements in the degree and manner of softening, and may also provide valuable collateral achievements in the same process. Satisfying results are best obtained from EXPERIENCE such as we have gained as pioneers and specialists in the field. We have been making successful applications of modern ion-exchange methods ever since the year the new resins were introduced. *Please tell us your wishes, and let us offer a suggestion.*

ILLINOIS WATER TREATMENT CO.
ionXchange
ILLCO-WAY
832 CEDAR ST.
ROCKFORD,
ILLINOIS
NEW YORK OFFICE: 141 E. 44TH ST., NEW YORK 17, N. Y.
CANADIAN DIST. PUMPS & SOFTENERS, LTD. LONDON, ONT.

GRACE CHEMICAL

(*Continued from page 77*)

from the decanter is further processed to recover solid urea by one of two paths. One process path produces a prilled grade of urea, which is used as fertilizer or as a cattle feed supplement. The other process path produces crystalline urea, suitable for applications requiring a purer grade material.

In order to produce fertilizer grade urea, the solution from the decanter is vacuum evaporated to a concentrated state, and then sprayed into air at the top of a tall tower where it is cooled and solidified into prills about the size of large grains of sand. The prills are cooled, dusted with a small percentage of clay to prevent sticking, and conveyed to bagging and storage.

Crystalline urea is produced by purifying the water solution obtained from the decanter, removing the last traces of unreacted raw materials, filtering, and crystallizing in a large vacuum crystallizer. The crystals are recovered by a centrifuge, dried in a rotary kiln, and then conveyed to bagging and storage.

NEW FERTILIZER PRODUCED AS COKE OVEN BY-PRODUCT

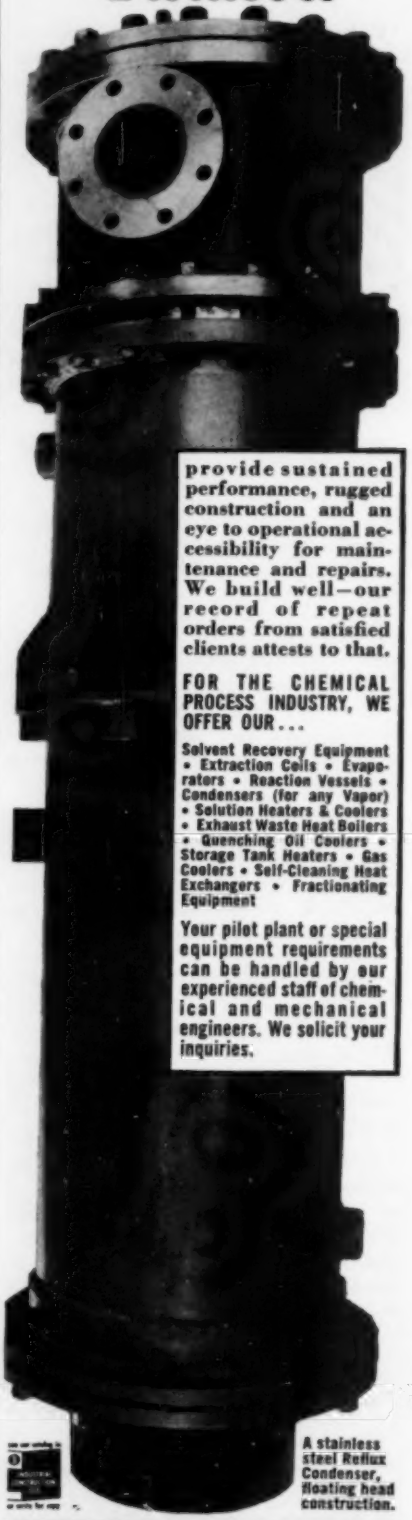
Diammonium phosphate is taking the place of ammonium sulfate as a fertilizer by-product of coke oven operations. Successful changeover of the first coke oven has been announced with the production of diammonium phosphate by the Colorado Fuel and Iron Corporation, Pueblo, Colorado.

Only relatively minor changes had to be made in present production facilities to accomplish the change. Instead of removing the ammonia from the coke oven gases by scrubbing through sulfuric acid, CF&I has substituted electric furnace phosphoric acid. The practicability of the method has proven itself in full scale plant production tests.

FLUOR ADDS NEW RESEARCH FACILITIES

A pilot plant area for testing large equipment used in the processing industries and a 17,000 sq.ft. laboratory comprise a new research center recently opened by the Fluor Corporation in Whittier, Calif. The two-acre site adjoining the plant for the pilot plant construction and operation presently have projects going on a pilot compression station, a plant for fertilizer studies, a solvent extraction test plant, evaporative cooling test apparatus, and a unit for checking performance of heat exchangers.

heat exchangers
BY
Paracoil



provide sustained performance, rugged construction and an eye to operational accessibility for maintenance and repairs. We build well—our record of repeat orders from satisfied clients attests to that.

FOR THE CHEMICAL PROCESS INDUSTRY, WE OFFER OUR...

Solvent Recovery Equipment • Extraction Cells • Evaporators • Reaction Vessels • Condensers (for any Vapor) • Solution Heaters & Coolers • Exhaust Waste Heat Boilers • Quenching Oil Coolers • Storage Tank Heaters • Gas Coolers • Self-Cleaning Heat Exchangers • Fractionating Equipment

Your pilot plant or special equipment requirements can be handled by our experienced staff of chemical and mechanical engineers. We solicit your inquiries.

A stainless steel Reflux Condenser, floating head construction.

DAVIS ENGINEERING
CORPORATION
1058 East Grand Street, Elizabeth 4, N. J.
30 Rockefeller Plaza, New York 20, N. Y.

PEOPLE

William I. Burt, 1952 president of the A.I.Ch.E., has been elected president of Goodrich-Gulf Chemicals, Inc.

Mr. Burt is also vice-president - manufacturing of B. F. Goodrich Chemical Co., a division of B. F. Goodrich. He joined the company in 1927 serving in the capacities of manager of the Akron, Ohio, chemical plant, general manager of plants, and superintendent of the chemical division before assuming the duties of vice-president-manufacturing.

He is a graduate of Ohio State university with a degree in chemical engineering.

Edward H. Smoker takes over the office of president of United Gas Improvement Company succeeding Walter E. Long who retires after 50 years of service with the company.

Mr. Smoker assumes his new position with the experience of 24 years in the firm during which time he served in various capacities including his more recent ones of operating manager and then vice-president in charge of operations. Mr. Smoker earned his doctorate degree from the University of Cincinnati.

U.G.I. announced also the appointment of **W. D. McElroy** as operating manager. Mr. McElroy came to the company in 1928 as technician in the physical laboratory. He has held subsequent positions as manager of the lab and plant superintendent, and engineer in the operating department. Mr. McElroy holds a B.S. and M.S. degree in chemical engineering from West Virginia University.

Eli I. Goodman has been appointed chemical engineer for the Nuclear Science and Engineering Corporation of Pittsburgh with responsibility for advancing the corporation's program of applying nuclear engineering to wide industrial use.

Frank B. Varga becomes manager of the project department of the chemical division of Koppers Company, Inc. Mr. Varga spent the last two years in Brazil representing Koppers in plastic manufacturing operations.

John A. Phinney takes over the position of research manager of the research and development division of Pittsburgh Consolidation Coal Company.

(Continued on page 97)

NEW
Arnold O. Beckman
MODEL F3
OXYGEN ANALYZER

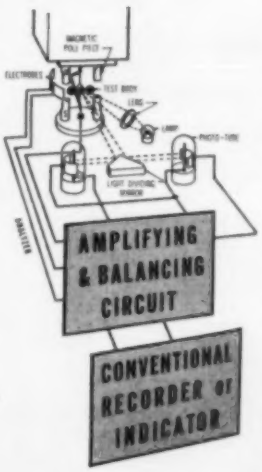
with the meter on the door

New convenience has been built into the well-known F3 Oxygen Analyzer . . . a meter on the door provides readings at the sampling point for making calibration checks, process changes, etc. In fact, complete analyzing, calibrating and indicating components are now incorporated into the single F3 unit—at no extra cost!

Use The Model F3

ON OPERATIONS LIKE THESE . . . TO MAKE SAVINGS LIKE THESE

COMBUSTION **Boilers, Kilns, Direct-Fired Heaters, Stills, etc.**	*Higher combustion efficiencies, at lower fuel costs*
PROCESSING **Air Liquifraction . . . Processing Butadiene, Acetylene and Similar Gases**	*Better product quality with minimum oxygen or air contamination*
PLANT SAFETY **Hydrogenation, Hydrofining, Gas Compressors, Sulfur Grinding, etc.**	*Control explosive atmospheres, reduce fire risks, minimize plant and personnel hazards*



FEATURES OF THE F3

Many Ranges: Full scale ranges of 0-5%, 0-10%, 0-15% O_2 and higher.
Accuracy: 1% of full scale.
Multi-Ranges: Any instrument may be supplied with two or more ranges.

Note: For ranges narrower than 0-5% O_2 ask about the Model G2.

Unique Operating Principle

The various applications highlighted above are only a few of the many ways Arnold O. Beckman Oxygen Analyzers—industry's great new profit builders—are being used by progressive operators to boost profits, cut costs.

These are the *only* oxygen analyzers that *continuously* measure process streams by an advanced magnetic principle that provides *direct physical measurement of the oxygen itself*—not of some secondary relationship.

Heart of the unit, as illustrated, is a dumbbell-shaped test body suspended in a magnetic field. Sample gas surrounding this test body causes it to rotate in the field, depending upon the oxygen content of the gas. The movement of a light beam, reflected by a small mirror on the test body, is measured by simple electronic circuits . . . and the result indicated directly on a conventional recorder or indicator. It's simple, positive, accurate!

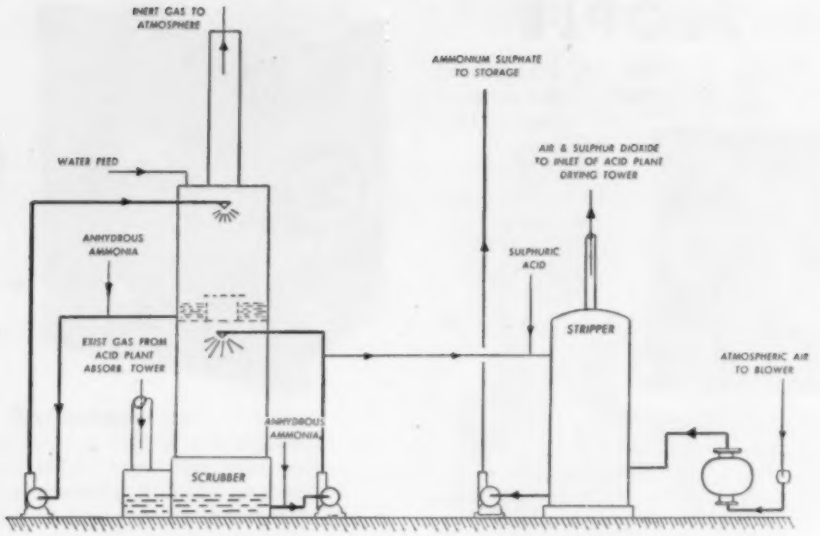
No chemicals—filaments—catalysts cams—complicated mechanical parts!

***Send for Helpful Free Literature** which describes this unique operating principle in detail—explains its many advantages and applications. When writing, outline your particular operations—we'll gladly supply specific information.*

Ask For Data File 16A-25

Arnold O. Beckman INC.
Instruments for Science and Industry
1020 MISSION STREET
SOUTH PASADENA, CALIFORNIA

new process increases sulfuric acid capacity



Increases in production capacity as high as 20% in contact sulfuric acid plants have been demonstrated by using a new 2-stage exit gas scrubbing process. The new process known as the Cominco SO_2 Recovery Process and developed originally by the Consolidated Mining and Smelting Co. of Canada is being licensed in the United States by the Olin Mathieson Chemical Corporation.

The economic loss of sulfur as exit gases, normal in the most efficient rates of operation of contact sulfuric plants, can be minimized by the Cominco 2-stage scrubber which returns this sulfur to the production unit. The scrubber is designed to handle SO_2 concentration as high as 0.9%. The over-all absorption efficiency is very high with tail gases containing less than .03% sulfur dioxide.

Plants equipped with the Cominco system can be operated at rates well in excess of normal capacity. Because substantially all the unconverted sulfur is recovered and reprocessed, these higher production rates are practical, even though conversion of the sulfur to sulfuric acid is less efficient.

The process can be used on any gas stream containing sulfur dioxide, such as may occur in smelting and petroleum refining operations, therefore in areas where discharge of SO_2 from the stacks creates an air pollution problem, this process provides effective abatement, at the same time disposing of the recovered sulfur to avoid water pollution.

The first system utilizing the Cominco process in the United States was put into operation at the Olin Mathieson Pasadena, Texas plant. There the 2-stage scrubber, using ammonium sulfite-bisulfite scrubbing solution, returns sulfur to the production unit and converts part of the acidic values in the exit gases to ammonium sulfate. Olin Mathieson pipes the ammonium sulfate to its fertilizer manufacturing operation, but the sulfate can also be recovered as crystals. The entire unit is automatically controlled and requires no additional personnel for its operation.

The flow diagram describes the layout and operation of the Cominco SO_2 Recovery System.

Olin Mathieson has established a Western Sulfur & Acids Division at Little Rock, Arkansas, which will offer engineering consulting service or will undertake design, installation and initial operation of the process under contract to licensees.

PEOPLE

PEOPLE

(*Continued from page 95*)

Dr. William H. Schuette has advanced to the position of assistant to the general manager of the Midland division of the Dow Chemical Company.

Dr. Schuette joined the company in 1941 and served in successive positions beginning in the chemical engineering laboratory to styrene monomer production and finally as plastics production manager before assuming his present job.

With a chemical engineering degree from the Case Institute of Technology, Dr. Schuette came to Dow with background as an instructor at Case and experience in the field with the National Carbon Co. and the C. O. Bartlett and Snow Co.

Dr. Robert W. Krebs is promoted to associate director of the Esso Laboratories of the Standard Oil Development Company.

In other executive changes in the company, **Dr. Lindsey I. Griffin, Jr., Frank B. Johnson** and **Charles N. Kimberlin** were appointed assistant directors with **Dr. Robert E. Wood** as acting assistant director in the company.

Robert F. Schultz is promoted to production superintendent of the headquarters plant of Hooker Electrochemical Co. in Niagara Falls.

Mr. Schultz joined Hooker in 1941 having just earned a master's degree in chemical engineering from the University of North Dakota on a graduate fellowship.

Robert J. Phillips will manage the treating division and be active in process engineering work for the desalting division of Howe-Baker Corp. in his new position with this company.

Mr. Phillips comes to Howe-Baker from PETROLEUM REFINER where he was editorial director.

Charles B. Roen is named an assistant director of the engineering department of the research and engineering division of Monsanto Chemical Company with his headquarters in Dayton, Ohio.

Max Key replaces Dr. William H. Schuette as manager of the plastics production department of the Dow Chemical Company.

(*Continued on page 98*)

Ingersoll-Rand

EJECTORS

assure trouble-free vacuum production

The simplicity and rugged three-piece construction of I-R steam-jet ejectors assure efficient, low cost operation year after year—free from internal leakage, mis-alignment problems or maintenance.

I-R ejectors are the *simple* and *economical* means of producing vacuum to remove air, gas and vapors from condensers and vacuum chambers. Contact your nearest Ingersoll-Rand branch office for information on your next evacuation problem, or write for Bulletin 9013-A.

4-131

Ingersoll-Rand
11 Broadway, New York 4, N. Y.

PUMPS • COMPRESSORS • TURBO-BLOWERS • VACUUM EQUIPMENT
AIR & ELECTRIC TOOLS • GAS & DIESEL ENGINES

COLTON ROTARY PRESSES

CAPACITIES 65 TO OVER **5000** TABLETS PER MINUTE

MIXERS—GRANULATORS—OVENS

FOR HIGH PRODUCTION AT LOW COST

ARTHUR **COLTON** COMPANY
Established 1887
Div. Snyder Tool & Engineering Company
3517 E. LAFAYETTE • DETROIT 7, MICHIGAN

Francis E. Reese advances from

PPC

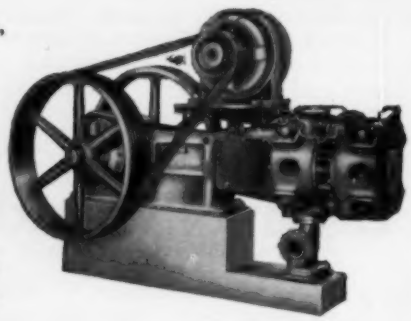
THIS DROP OF OIL
IS GOOD FOR MOST MACHINERY

but . . . it is bad in the food you eat, the beverages you drink and disastrous in some chemical processing when it leaves the machine and gets into your product.

That's why more people like you are buying our OILFREAIR and OILFREGAS Compressors guaranteed to compress air and gas entirely free of any trace of oil or oily vapor.

It's a fact you cannot effectively separate oil vapor from compressed air and that's why the only sure cure for contamination is to prevent it at the source.

Bulletin 600-3, yours for the asking, describes these compressors.
Write today.



PENNSYLVANIA PUMP AND COMPRESSOR COMPANY
EASTON, PENNA.

OILFREAIR ® OILFREGAS ® THRUSTFRE ® AIRCHEK ®

TANK-O-METER
FOR MEASURING TANK CONTENTS ANY DISTANCE AWAY

TANK MAY BE BURIED, ELEVATED, OPEN, CLOSED, VENTED OR UNDER PRESSURE OR VACUUM

ALSO . . .
HYDROSTATIC GAUGES
FOR ALL PURPOSES
PRESSURE • VACUUM • DRAFT
DEPTH & ABSOLUTE PRESSURE
DIFFERENTIAL PRESSURE
MERCURIAL BAROMETERS

SEND FOR BULLETINS

UEHLING INSTRUMENT CO.
487 GETTY AVE., PATERSON, N. J.

BIND YOUR C.E.P. IN THE NEW, STURDIER BINDER

CHEMICAL ENGINEERING PROGRESS
25 West 45th Street
New York 36, New York

Gentlemen: I am enclosing my check (money order) for $..... Please send me ..... binders @ $3.50 each for the following years (add 3% sales tax for delivery in New York City): .....

.....

Name: .....

Address: .....

City: .....Zone: ....

State: .....

PEOPLE

(*Continued from page 97*)

After 35 years of service, one of the longest terms in the history of the company, **F. J. Bartholomew** has retired from the Chemical Construction Corporation.

Mr. Bartholomew began his career with Chemico in charge of research and development and at the time of his retirement was assistant secretary and sales executive. He also has directed the firm's advertising policies.

Among his credits is the invention of the Hot Coke Sludge Conversion Process as well as other chemical processes. His Chemico Acid handbook is widely used in the acid industry.

Mr. Bartholomew was graduated from Lehigh university with degrees in chemistry and chemical engineering.

On January 20 **Milton C. Whitaker,** retired vice-president of American Cyanamid Company was conferred with an honorary membership in the American Institute of Chemists.

Dr. Whitaker, now 84, is still active as a consultant to Cyanamid. His career includes a professorship of chemical engineering at Columbia, and editorship of *Industrial & Engineering Chemistry* prior to taking a direct part in industry.

His citation was presented by Donald B. Keyes of A. D. Little, Inc., national president of the AIC.

Mobay Chemical Company announces **Dr. W. R. McElroy** to head the process development group investigating processes for products and intermediates, and **Andrew S. Morecroft** as head of the isocyanate foam group engaged in applied research on flexible and rigid foam systems.

Richard E. Cocks takes over the position of plant superintendent of the plant food division of Farm Bureau Services, Inc.

CORRECTION

In the December issue of C.E.P. on page 91, we regret listing incorrectly Homer Z. Martin as having been director of the development division of Standard Oil Development Co. in Linden, N. J., and Henry J. Ogorzaly as new director of this division. As of that time the item should have listed Mr. Martin as assistant director and Mr. Ogorzaly as taking over the assistant directorship position.

You gotta be first...

to be best!*

*25 years ago, Alloy Fabricators started to build Stainless Steel, Monel, Inconel, Nickel and Aluminum Process Equipment. With this experience, naturally, they're your best bet today!

It's Still Our Only Business — And We Mind It Well!

ALLOY FABRICATORS

PERTH AMBOY, NEW JERSEY

SNELL Research Includes

Product Development
Product Improvement
Processing Evaluation
Packaging Evaluation
Physical Properties
Chemical Properties
Flavor Determination
Stability Determination
Engineering

Initial consultation involves No Cost or Obligation

inquiries invited

RESEARCH LABORATORIES

FOSTER D. SNELL INC.

29 WEST 15TH ST. NEW YORK 11, N.Y. — WA 4-8800

CHEMISTS · ENGINEERS

Francis E. Reese advances from assistant division engineer to associate director of engineering for the plastics division of Monsanto Chemical Company.

In his new job Mr. Reese will be responsible for project, design, utility, construction and development activities of the Springfield section of the division engineering department.

Mr. Reese joined Monsanto in 1941 after having earned a B.S. degree in chemical engineering from Purdue university. He has been a member of the A.I.Ch.E. since 1946.

Dr. John T. Rucker, Jr., advances to the position of administrative assistant to the director of research and development at Hooker Electrochemical Co., Niagara Falls.

A graduate of the University of Virginia in chemical engineering, Dr. Rucker earned his doctorate in 1941 from the University of Cincinnati and joined Hooker that same year. He has been granted six patents with six additional patent applications pending.

Joining International Minerals & Chemical Corporation's phosphate chemical division as project engineer, **Sanford R. Bell** has been promoted to plant engineer of the company's Bonnie, Fla., chemical plant.

Robert J. Schatz is named associate director of research at the Springfield lab of the plastics division of the Monsanto Chemical Company.

Dr. Shatz adds to his present duties of administrative supervision of the Seattle and Santa Clara labs with new responsibilities in Springfield.

Dr. Shatz came to Monsanto with a master's degree in chemical engineering from Lehigh university and his doctorate in physical chemistry from Cornell university.

Scientific Design Co. announces the appointment of **Thomas P. Brown** as vice-president of the company.

At the same time **Henry F. Peters** becomes assistant vice-president of the engineering department and **David Brown** assistant vice-president of the development department.

Norman Barson and **Bert W. Struth** join the staff of Esso Engineering of the Standard Oil Development Company. **Hubert A. Pattison, Jr.,** is a new addition to the staff of the patent division of the company.

NEWS from FILTERTOWN

Extremely versatile E&D #613 is equally at home in the laboratory and the industrial plant.

In the former, it is used for analysis of blood to determine sugar content, for hospital analysis tests and as indicator papers.

In the latter, it is used for filtration of such widely diversified products as fruit juices, colognes, drugs, medicinal oils, pharmaceuticals, salt solutions and bees wax.

The physical characteristics of grade #613 are: .006 inches thick, smooth surface, rapidity 60, wet strength 4.8.

We, however, are the very first to admit the likelihood that it does some jobs better than others. And by better, we think in terms of clarity of filtrate, rapidity and economy.

Thus, we continually stress the advisability of permitting our know-how to help you select the right grade of filter paper for your particular filtration process — or product.

Since E&D has sixty-five years of experience and research tucked away, and since E&D is the only company in America exclusively devoted to the manufacture of filter paper, there's a more than reasonable chance that we can be of help to you.

Write for free samples.

And ask for our Filtration Analysis Report if you have any doubts about whether you're using the right filter paper. No obligation, at all.

E&D FILTER PAPER

THE EATON-DIKEMAN CO.
FILTERTOWN
MOUNT HOLLY SPRINGS, PA.

CLASSIFIED SECTION

Address Replies to Box Number Care of CHEMICAL ENGINEERING PROGRESS

SITUATIONS OPEN

ENGINEER
Materials & Processes

This newly created position is now available at Electric Boat Division of General Dynamics Corporation, designers and builders of the world's first atomic-powered submarines.

It requires a degree in mechanical, chemical or metallurgical engineering, minimum ten years' experience in materials applications in process industry or chemical field, with strong background in material application and metallurgy and some chemical knowledge. Will coordinate fields of power plant and ship design materials specifications and application, corrosion, cleaning methods and procedures, welding and other special material techniques.

The man who qualifies can look forward to a long and rewarding association with an organization known for the stable employment of its engineering personnel . . . a relaxed way of life on the Connecticut shore near New London (half way between New York and Boston).

Applications will be reviewed promptly and confidential interviews arranged for qualified men. Please submit complete résumé, including initial salary requirements, to Mr. Peter Carpenter, Technical Employment Supervisor.

Electric Boat Division

GENERAL DYNAMICS CORP.

GROTON **CONNECTICUT**

Chemical Engineers

To process-engineer new oil-refineries and chemical plants. The work is basically process-design, plant-layout, equipment selection, and economic evaluation.

Please send your résume to our Personnel Department. Your letter will receive immediate and confidential attention.

C F BRAUN & CO

Engineers
Constructors

ALHAMBRA, CALIFORNIA

ENGINEERS OR PHYSICISTS
FOR RESEARCH PERTAINING TO ROCKET PROPULSION

Recent graduates with professional degree or Ph.D. received since 1945 are required for:

1) Research in combustion stressing fluid dynamical aspects.
2) Research in non-steady fluid flow with energy and mass transfer.

Research engineer and test engineer (MS, mechanical or chemical) are required to engage in experimental programs.

Airmail your summary of qualifications to:

Caltech JET PROPULSION LABORATORY

4800 Oak Grove Drive, Pasadena 3, California

SENIOR FURNACE ENGINEER

The design of furnaces to improve process service requires exceptional training and ability. We'd say the minimum was an ME or ChE degree, 8 years' background in furnace design, and a thorough knowledge of heat transfer fluid flow, chemical reaction, metallurgy and strength of materials as applied to furnace design.

The ability to recommend desirable process changes, to develop new designs and design methods requires additional talents as well as initiative.

If you can meet these exacting qualifications, we'd like to meet you. The result can be mutually profitable.

Box #539, Room 1201
230 West 41 St., New York 36, N. Y.

CHEMICAL ENGINEER—PHYSICAL CHEMIST

Department of Chemical Engineering and Applied Chemistry

UNIVERSITY OF TORONTO

There is an opening on the professorial staff for a chemical engineer well grounded and interested in physical chemistry, or a physical chemist who has an engineering background. Research interests or experience in the field of petroleum is highly desirable. Address inquiries to R. R. McLaughlin.

FILTRATION ENGINEER—We have very attractive position for man experienced in sale of pressure-filtration equipment. Prefer man with experience in both plate and frame filtration. Salary open. THE EIMCO CORPORATION, 3140 Fayette Avenue, Birmingham, Ala.

CHEMICAL ENGINEERS—Excellent opportunities in plant-design and development work in the Southwest. United Carbon Co., Inc., Box 1913, Charleston 27, W. Va., Attention Technical Director.

CHEMICAL ENGINEER—Opportunity for a young chemical engineer interested in pilot-plant and plant-project engineering to fill a responsible position in a small progressive company. Excellent possibilities for growth and advancement. Please address replies to The Carwin Company, North Haven, Conn.

SITUATIONS WANTED

A.I.Ch.E. Members

PROJECT ENGINEER—P.E. Cost estimates and construction proposals prepared for selected processes in organics, fats, oils, detergents, and pharmaceuticals. Flow sheets and layouts. Consulting basis only. Northeast. Box 1-2.

CHEMICAL ENGINEER—B.S. Twenty years' diversified experience: eight years' heavy chemical production, twelve years' production, maintenance, administration in fine chemicals, antibiotics and pharmaceutical field. Broad experience distillation and industrial waste disposal. Professional engineer. Present salary $9,600. Desire responsible position with future. Box 2-2.

CHEMICAL ENGINEER—Heavy experience foods, including production, development, design of processes and machines. Will head research or production same. Now with leading canner. Reg. Chem. and Mech. Engineer. Member A.C.S., I.F.T. Box 3-2.

DIRECTIONS FOR USE OF CLASSIFIED SECTION

Advertisements in the Classified Section of Chemical Engineering Progress are payable in advance at 15c a word, with a minimum of four lines accepted. Box number counts as two words. Advertisements average about six words a line. Members of the American Institute of Chemical Engineers in good standing are allowed one six-line Situation Wanted insertion (about 36 words) free of charge a year. Members may enter more than one insertion at half rates. Prospective employers and employees in using the Classified Section of Chemical Engineering Progress agree that all communications will be acknowledged; the service is made available on that condition. Boxed advertisements are available at $15 a column inch. Size of type may be specified by advertiser. Answers to advertisements should be addressed to the box number, Classified Section, Chemical Engineering Progress, 25 West 45th Street, New York 36, N. Y. Telephone COlumbus 5-7330. Advertisements for this section should be in the editorial offices the 15th of the month preceding publication.

EXECUTIVE CHEMICAL ENGINEER—Twenty years' extensive, diversified supervisory experience in process engineering, sales, and research. Presently director of technical department, chemical process company. Desire increased opportunity in management of progressive company, about $20,000. Box 4-2.

CHEMICAL ENGINEER—Total 15½ years' progressive experience in organic chemical plant engineering and construction. Nine years' success as a process-project engineer. 2½ years' diverse experience in maintenance, development, and operating of plants. Age 38, married, family. Licensed professional engineer. East Coast preferred. Box 5-2.

TECHNICAL MANAGEMENT—Chemical Engineer, Sc.D., wants responsible position in technical or management fields. Has managed research, development, engineering, and production during twenty-five years' broad experience in petroleum, chemicals, minerals, waste disposal, fermentation, foods. Box 6-2.

TEACHING—Ph.D., Chemical Engineer, age 39. Now employed in process design and development by major chemical company, but would like to return to academic life. Fifteen years' diversified experience in teaching and industry. Major interests—heat transfer, applied kinetics and thermodynamics. Box 7-2.

CHEMICAL ENGINEER—Management and coordination major chemical process and engineering projects. Last ten years engaged in most progressive programs in field of organics and petrochemicals. Ph.D. Present salary $15,000. Desire manager development, chief engineer, or similar. Box 8-2.

MIDWEST SALES ENGINEER, Ch.E.—Chemical process equipment, valuable following throughout industrial Midwest. Desires representation or salary-commission arrangement. Headquarters Cleveland. No other lines. Age 40. Box 9-2.

D. ENG.—Age 32, engineering manager of atomic energy project, four years' experience as assistant professor, publications. Desires teaching or research supervision post in New England. Box 10-2.

YOUNG Ph.D. CHEMICAL ENGINEER—ACADEMIC ADMINISTRATOR; age 32; married; six years' teaching; industrial and research experience; four years as research project supervisor; currently in charge of department employing thirty technical people. Desires challenging supervisory position in industry with good opportunities for advancement. Salary requirements: $10,000. Box 11-2.

NUCLEAR ENGINEER, Ch.E.—Age 35. Degrees in chemical engineering plus ten years' atomic energy experience. Capable, alert, and seasoned by responsible positions. Salary requirements $10,000. Don't pass this up. Box 12-2.

CHEMICAL ENGINEER—B.Ch.E. Age 32, family. Seven years' development and process engineering in radioactive and heavy chemicals fields. Pilot-plant supervisor. Desires responsible position in development or process design. New York-New Jersey area. Box 13-2.

PROCESS ENGINEER—B.S., M.I.T. Eight years' diversified experience in process and project engineering for petrochemicals, petroleum, tonnage oxygen, and low-temperature separations, from sales contact to plant start-up. Desires challenging position with future. Box 14-2.

CHEMICAL ENGINEER—Age 29, B.S.Ch.E., registered engineer. Five years' experience process design, development, and production in heavy inorganic, extractive metallurgy, and ore-dressing fields. Two years' equipment and process development in food industry. Box 15-2.

CHEMICAL ENGINEER—Twenty years' experience in plant management, process development, engineering, and installation with a wide variety of inorganic and organic processes. Successful background plant operation, labor relations, cost control, new-project evaluation. Seeks connection in plant management, development, or engineering. Registered P.E. Available thirty days. Box 16-2.

PLANT ENGINEER—B.S.Ch.E., 1943. Family. Ten years' diversified experience in production, design, and construction. Eight years' supervisory experience. Well qualified for project work in chemical processing. Desires Southwest location. Available April 15. Box 17-2.

CHEMICAL ENGINEER—B.S., 1950. Age 28, married, veteran. Four and a half years' varied experience in process development, pilot-plant supervision, and plant technical assistance. Box 18-2.

CHEMICAL ENGINEER SEEKS CHALLENGE of increased production supervision or broadening experience in commercial areas of expanding company. Six-year record of cost reduction, equipment break-in, good personnel relations. Age 29, married. Box 19-2.

CHEMICAL ENGINEER—B.Ch.E., 1952. Veteran. Experience in production planning, personnel supervision, industrial instrumentation, engineering design and development, production engineering. Desires a permanent position in the greater New York City area. Box 20-2.

AGGRESSIVE, TACTFUL, CHEMICAL ENGINEER—Professional engineer, B.Ch.E., M.Ch.E., married ten years. Strong background in project engineering, also process design, trouble-shooting operations, construction liaison. Earning $9,000 plus. Seeks maximum challenge. Box 21-2.

Nonmember

CHEMICAL ENGINEER—M.S., 1951. Seven years' experience in process development and evaluation work including fine grinding, particle sizing, air-pollution studies, and explosives development. Supervisory and report-writing experience. Desires challenging and responsible position in process-product development. Available immediately. Age 32, family, veteran. Box 22-2.

ASEE SUMMER SCHOOL

The American Society for Engineering Education Institute on Thermodynamics and the Chemical Engineering Division Summer School will be held from June 27 to July 1 at Pennsylvania State University, State College, Pa. Requests for information and registration forms should be addressed to Prof. K. L. Holderman, 103 Mechanical Engineering Division, Pennsylvania State University.

Necrology

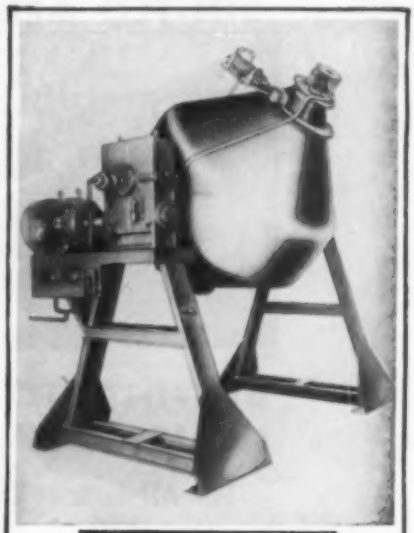
Chemical Engineering Progress recently was notified of the death of the following members:

Dr. Max Jakob, 75, research professor of mechanical engineering at Illinois Institute of Technology and consultant in heat research at Armour Research Foundation.

Dr. Jakob was considered a foremost authority on heat transfer and thermodynamics. He founded the heat transfer laboratory at Illinois Institute which has been developed into a center for graduate research having students from all over the world.

Receiving his education in engineering at the Royal Institute of Technology in Munich, Dr. Jakob came to the United States in 1936 after having participated in extensive research in his

(*Continued on page* 102)



GEMCO

Double Cone Blender

1. Rugged Steel Supports — No additional foundation work required — Clearance from base of valve to floor to suit purchaser's requirements.
2. Control — Retractable charging and unloading device.
3. Brake — for accurate positive positioning — Motor or floor mounted.
4. High starting torque, totally enclosed, fan cooled motor.
5. Totally enclosed, worm and wheel oil-immersed, vibration free GEMCO SPEED REDUCER.
6. Control — Air-operated Valve mounted on control panel.
7. Heavy Welded Plate Shell (choice of steel, s/s, etc.) All welds on ID ground smooth — Note curved center section to improve blending and also facilitate cleaning.
8. Balance casting — on hinged cover for easy access to interior.
9. Gemco air-operated valve — guaranteed dust-proof and non-sifting of the finest materials even when Blender is operating.
10. Air-operated charging and unloading device — designed to fit hopper and container.

Write for complete information in this FREE booklet

GENERAL MACHINE COMPANY OF NEW JERSEY

400 Market Street **Newark 5, N. J.**

Name _____

Company _____

Street _____

City & State _____

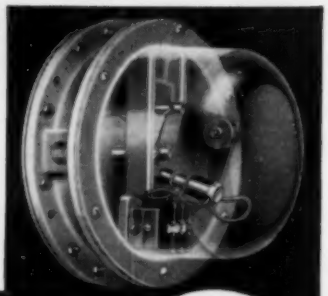
BIN-FLO AERATING UNIT

Provides Steady Flow of Dry, Finely Ground Materials which tend to bridge in storage. Uses only small amount low-pressure air.

BIN-DICATOR BIN LEVEL INDICATOR

For All Bulk Materials

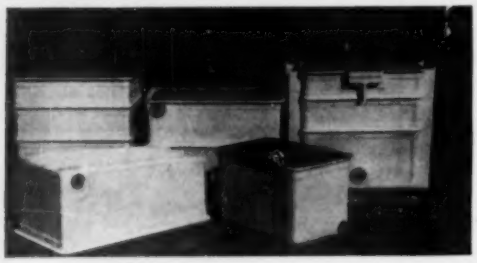
signals change in level; automatically starts and stops filling and emptying equipment.



THE BIN-DICATOR CO.
13946-H Kercheval • Detroit 15, Mich.

NEW DETAIL DATA BOOK FREE

For Corrosion Resistance! Electrical Insulation!



TANKS! *Just name your Shape and call your Size . . . .*

Whether round, square, huge or stunted, BONATE can build them! And better! Light in weight, easy to handle and install, Bonate Tanks provide that much needed processing *plus* . . . they're corrosion resistant and electrically insulative. Specified provision for Pipe connecting flanges, Bosses, Bus bar supporting ribs and Threaded holes present no problem. Write. Ours are the Tanks that win Thanks!

CUT COSTS! –with **Bonate**

Glass Reinforced POLYESTER, EPOXY, PHENOLIC **LAMINATES**

Carl N. Beetle PLASTICS CORP.

MOLDERS & FABRICATORS processing, plating, storage & truck tanks; ducts, pipe, stacks, parts, etc.

145 Globe Street
Fall River, Mass.
Tel: 7-9464

NECROLOGY

(*Continued from page* 101)

field as research engineer, consulting engineer and magazine editor.

Just before his death Dr. Jakob completed the second volume of a textbook "Heat Transfer" which will be added to his list of literary, accomplishments including many books and over 300 scientific papers.

Raymond F. Bacon, 74, New York City consulting chemical engineer.

Dr. Bacon spent much of his career in the field of education having begun as an instructor in chemistry at DePauw university after earning a B.S. degree from that school in 1899. He went on as professor of chemistry at Vincennes university and in 1904 received his Ph.D. from the University of Chicago.

Dr. Bacon continued as chemist for the Bureau of Science in Manila and thereafter published several pieces on Philippine terpenes and essential oils. On his return to the United States, Dr. Bacon served as Senior Fellow in the industrial research lab at the University of Pittsburgh and as professor of organic chemistry. In 1913, he joined the Mellon Institute as associate director.

Dr. Bacon has been a member of the A.I.Ch.E. since 1916.

Ralph H. Fash, 70, consulting chemist with the Fort Worth Laboratories, Fort Worth, Texas.

After his graduation from the Armour Institute of Technology with a degree in chemical engineering, Mr. Fash joined Swift & Co. as chemist in the manufacture of crude glycerin and the operation of the fertilizer plant. He continued with the Chickasha Cotton Oil Co. in complete charge of cotton seed oil refining.

In 1916, Mr. Fash became consulting chemist under name of the Fort Worth labs. He joined the A.I.Ch.E. as an active member in 1940.

John R. Long, 46, research chemist for the Goodyear Tire & Rubber Co.

Dr. Long had been associated with Goodyear since 1950 where he directed a group of chemical engineers in process development of organic syntheses and the design and operation of research pilot plants.

He was graduated in 1933 from Kansas State college with a degree in chemical engineering. In 1937 he received his Ph.D. in organic chemistry from Ohio State university. Dr. Long began his career with Goodyear, spent three years as assistant professor of chemistry at Kent State university and then returned to Goodyear in 1950 after a brief period with the Pathfinder Chemical Corp.

INDEX OF ADVERTISERS

	Page
A	
Ace Glass, Inc.	96
Aerofin Corp.	91
Air Preheater Corp.	33
Air Products, Inc.	26
Aldrich Pump Co.	73
Alloy Fabricators Div.	99
Alsop Engineering Corp.	92
American Hard Rubber Co.	18
Armstrong Co., Richard M.	87
B	
Babcock & Wilcox Co., Tubular Products Div.	22
Badger Mfg. Co.	67
Barton Instrument Corp.	42
Bauer Bros., Inc.	92
Beckman, Inc., Arnold O.	95
Beckman Instruments, Inc.	15
Beetle Plastics Corp., Carl N.	102
Bethlehem Foundry & Machine Co.	39
Bin-Dicator Co.	102
Blaw-Knox Co., Chemical Plants Div.	17
Brown Fintube Co.	*Inside Back Cover*
C	
Chemical Corporation	78
Chemical & Industrial Corp.	13
Chicago Bridge & Iron Co.	71
Colton Co.	97
Condenser Service & Engineering Co., Inc.	60
Continental Copper & Steel Industries, Inc.	99
Cooper Alloy Corp.	65
Crane Company	8
Croll-Reynolds Company, Inc.	103
D	
Davis Engineering Co.	94
DeZurik Shower Co.	58
Dow Chemical Co.	36
Dow Corning Corporation	78
Doyle & Roth Mfg. Co., Inc.	79
Duraloy Company	89
E	
Eaton-Dikeman Co.	99
Eco Engineering Co.	81
Elliott Company	84
Ertel Engineering Corp.	58
Ethylene Chemical Corp.	64
F	
Filtration Engineers, Inc.	80
Floridin Company	82
Foster Wheeler Corp.	32
Foxboro Co.	16
G	
Garlock Packing Co.	62
General Machine Co. of New Jersey	101
Girdler Company, The	24, 29
Great Lakes Carbon Corp., Electrode Division	59
Gump Co., B. F.	3
H	
Hammel-Dahl Company	44
Haveg Corporation	12
Hermas Machine Co.	87
Hills-McCanna Co.	10
I	
Illinois Water Treatment Co.	94
Industrial Filter & Pump Mfg. Co.	21
Industrial Process Engineers	68
Ingersoll-Rand	97
J	
Johns-Manville	20, 69
Johnston Co., Inc., Herrick L.	90
K	
Kellogg Co., The M. W.	28
Koven & Bro., Inc., L. O.	37
L	
Lapp Insulator Co., Inc.	31, 35
Layne & Bowler Pump Co.	6
Lummus Company	43
M	
Manning & Lewis Engineering Co.	77
Milton Roy Co.	52, 53
Mixing Equipment Co., Inc.	*Back Cover*
N	
Nagle Pumps, Inc.	86
National Carbon Co.	11
Newark Wire Cloth Co.	66
Niagara Blower Co.	70
Nicholson & Co., W. H.	7
P	
Pacific Pumps, Inc.	19
Parsons Co., Ralph M.	9
Patterson-Kelley Co., Inc.	49
Pennsylvania Pump & Compressor Co.	98
Permutit Co.	23
Posey Iron Works	85
Potter Aeronautical Co.	83
Powell Co., William	27
Pressed Steel Co.	72
Proctor & Schwartz, Inc.	14
R	
Rockwell Mfg. Co.	4, 5
S	
Sargent's Sons Corp., C. T.	93
Schmeig Industries, Inc.	72
Schultz-O'Neill Co.	57
Snell, Inc., Foster D.	99
Sparkler Manufacturing Co.	63
Spray Engineering Co.	86
Stokes Machine Co., F. J.	75
T	
Taylor & Co., W. A.	76
U	
Uehling Instrument Co.	98
Union Carbide & Carbon Corp., National Carbon Co.	11
United States Gasket Co.	38
U. S. Stoneware Co.	52F
V	
Vanton Pump & Equipment Corp.	74
Vulcan Copper & Supply Co.	*Inside Front Cover*
W	
Wallace & Tiernan Co., Inc.	88
Whitlock Mfg. Co.	41
Y	
York Co., Inc., Otto H.	61

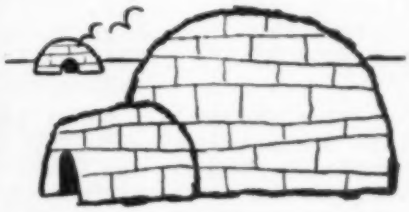
Advertising Offices

New York 36—Lansing T. Dupree, Adv. Mgr.; John M. Goede, Asst. Adv. Mgr.; Paul A. Jolcuvar, Dist. Mgr.; Donald J. Stroop, Dist. Mgr.; 25 W. 45th St., Columbus 5-7330.

Chicago 11—Richard R. Quinn, Dist. Mgr., 612 North Michigan Ave., Room 507, Superior 7-0385.

Cleveland 15—Douglas H. Boynton, Dist. Mgr., 1836 Euclid Ave., Superior 1-3315.

Pasadena 1—Richard P. McKey, Dist. Mgr., 465 East Union St., Ryan 1-8779.



Chill your process with a C-R CHILL-VACTOR

C-R CHILL-VACTOR units flash cool water, aqueous solutions and certain other liquids to temperatures down to 32° F. by partial evaporation at high vacuum.

As with all Croll-Reynolds equipment, the process is very simple. No chemical refrigerant is used. There are no moving parts. First cost as well as operating cost is usually less than for mechanical refrigeration.

CHILL-VACTOR units are producing chilled water in industrial plants throughout the world. Capacity varies from a few tons up to a few thousand tons.

The CHILL-VACTOR is only one type of steam-jet EVACTOR, manufactured by Croll-Reynolds. Others are producing high vacuum in many hundreds of plants. Let our technical staff help you with any or all of your vacuum problems.

CROLL C-R REYNOLDS

Croll-Reynolds CO., INC.

Main Office: 751 Central Avenue, Westfield, N. J.
New York Office: 17 John St., New York 38, N. Y.

CHILL-VACTOR UNITS • EVACTOR STEAM JETS • CONDENSING EQUIPMENT

news and notes

Nominating Committee is in the news again . . . At its January meeting Council appointed a group to function in 1955 . . . It is chairmaned by C. G. Kirkbride & has its membership geographically spaced about the country in order to ensure adequate representation of local interests . . .

Members are E. B. Chiswell representing the Pacific Coast . . . W. A. Cunningham the Southwest . . . R. C. Gunness the Chicago & Middle Central districts...George F. Jenkins, the South . . . George Lof the Rocky Mountain area . . . C. W. Nofsinger the Plains area . . . T. K. Sherwood New England . . . & Jesse Walton the Pacific Northwest . . .

Membership on this vital committee is elastic, as the Constitution specifies only that the committee shall be composed of at least five Members or Associate Members . . .

As explained previously in many of these columns, a by-law for nominating procedures calls for the Committee's slate to be ready eighteen weeks before the Annual meeting . . . this means July 25 of this year . . .

This was passed by Council to give local groups ample time to study the Nominating Committee choices before submitting nominations by petition . . . these, by the way, will be due in the Secretary's office not later than Sept. 25, 1955.

Council's deliberations this month were occupied to a great extent with policy matters . . . In the main, these were turned over to subcommittees for study and recommendation back to Council . . . More on these matters when the subcommittees report.

Deliberations on National meetings also occupied more time than usual . . . Approved was the recommendation of George Armistead's Program Committee that we hold a meeting at Seattle, Washington, June 9-12, 1957, with the Olympic Hotel as headquarters . . . (We promise to publish full information about salmon fishing and mountain climbing in our pre-meeting stories!) . . .

Bermuda meeting, which had been under study by Council for some time, finally was dropped . . . This had been examined critically by the Program Committee . . .

Gene Smoley of the Lummus Co. was doing the exploratory work & had presented an extensive report on his findings at the December meeting of Council . . . Final decision was made in January & though Smoley's report indicated such a meeting could be a success, Council felt that it might create misunderstanding of Institute purposes & motives.

Official representatives to Engineers Joint Council for the year 1955 are F. J. Van Antwerpen as representative & W. E. Lobo as alternate.

Student Chapter Counselors recently appointed by Council: Oddvar Solstad, University of Massachusetts . . . George M. Machwart, Michigan College of Mining & Technology . . . E. F. Johnson, Jr., Princeton University . . . G. D. Shilling, University of Rhode Island . . . Robert V. Jelinek, Syracuse University . . . Walter R. Pavelchek, Tufts College . . . V. W. Uhl, Villanova . . . Louis Maus, Jr., Lehigh University . . . Ralph A. Troupe, Northeastern University . . . J. M. Woods, Purdue University . . .

Council also approved the establishment of a Student Chapter of the Institute at the South Dakota School of Mines & Technology.

Official representatives of the A.I.Ch.E. to the 4th World Petroleum Congress will be B. F. Dodge, C. G. Kirkbride, & Eger V. Murphree, president of Standard Oil Development Co. & a director of the A.I.Ch.E. . . .

Murphree is also chairman of the United States National Committee for the 4th World Petroleum Congress.

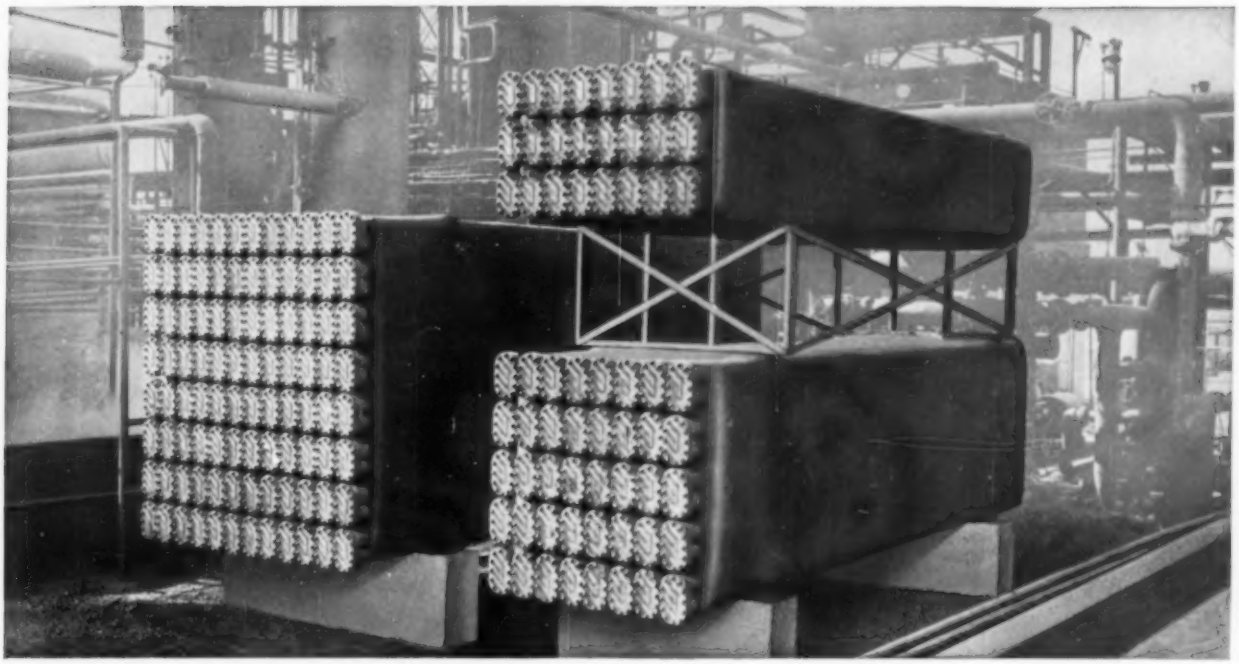
* * *

May I take this opportunity to thank all my friends in the Institute for the many kind wishes sent me on my succeeding to the position of Secretary . . . they are greatly appreciated . . . May I also thank the members for their confidence in me . . . & assure them of my determination to continue to aid the growth & well-being of the Institute & the profession.

F.J.V.A.

Six Reasons Why

you should specify



BROWN FINTUBE *Sectional* HEAT EXCHANGERS

FLEXIBILITY: If plant requirements change — and this is not uncommon — a "bank" of Brown Fintube heat exchanger sections can be disconnected and reassembled in different series-parallel arrangement easily and on short notice. "Bundle type" exchangers are not flexible. For them a change in duty usually involves designing — and waiting — for a whole new unit.

NO OBSOLESCENCE: Brown Fintube Sections never become obsolete. They can be used in one exchanger after another. Sections not in use serve as "standby" or parts, for other sections on stream.

REDUCED FOULING: Brown Fintube sections transfer more heat per lineal foot at lower surface temperatures. This minimizes coking. Also the longitudinal passages control the material flow eliminating eddies and reducing fouling.

EASY CLEANING: reduces maintenance costs. By manifolding just one extra parallel stream into an exchanger, the entire unit can be operated continuously — always clean — without ever coming off stream.

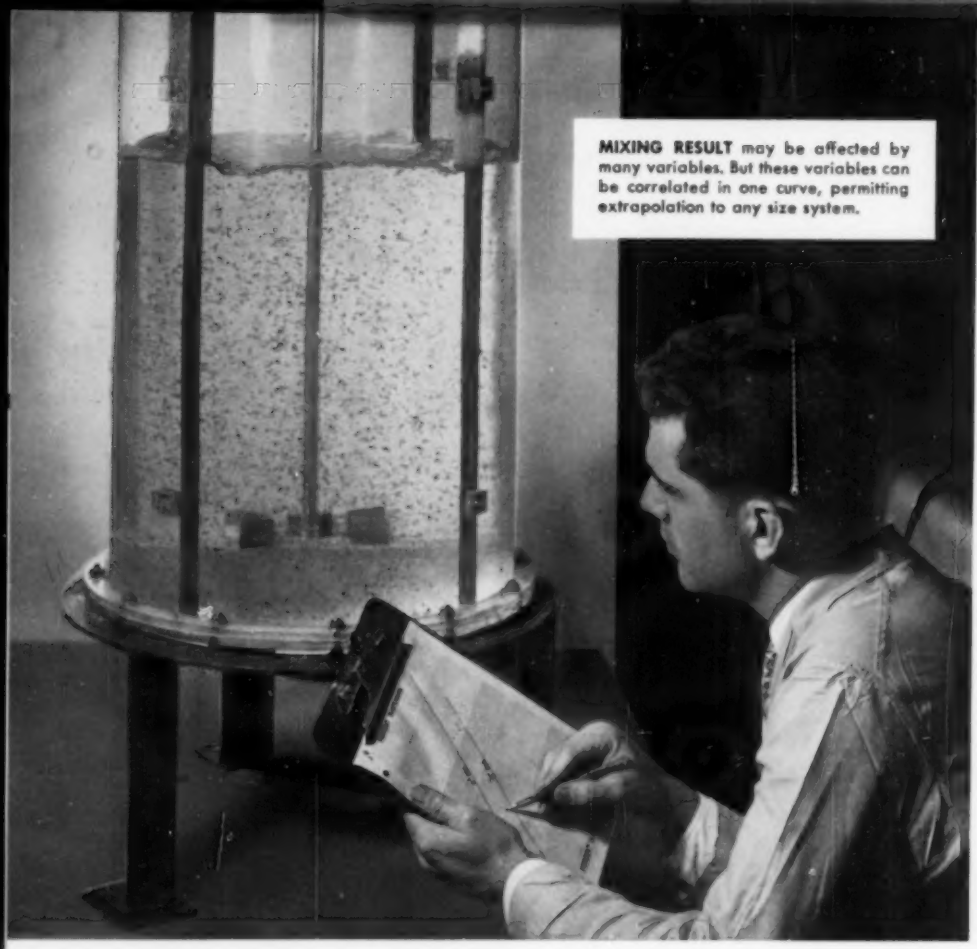
REDUCED STORES: Avoids tying up thousands of dollars in spare parts, housing and handling them.

PROMPT DELIVERY: Standardization permits economical assembly line manufacture from standardized parts — and prompt delivery.

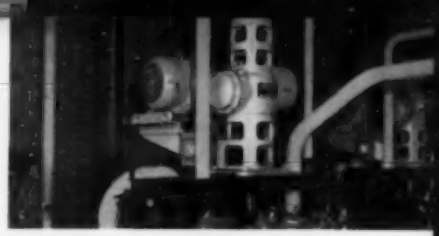
If you heat — or cool — liquids or gases in your plant, you'll get a lot of ideas from our Bulletin No. 512. Send for a copy!

BROWN FINTUBE CO.
Elyria, Ohio

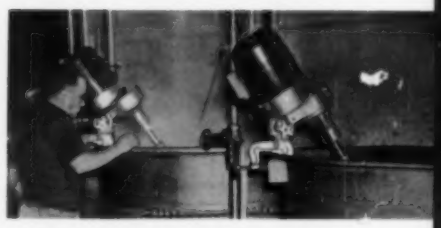
NEW YORK • BOSTON • PHILADELPHIA • PITTSBURGH • BUFFALO • CLEVELAND • CINCINNATI • DETROIT • CHICAGO • ST. PAUL • ST. LOUIS
KANSAS CITY • MEMPHIS • BIRMINGHAM • NEW ORLEANS • SHREVEPORT • TULSA • HOUSTON • DALLAS • DENVER • LOS ANGELES • SAN FRANCISCO
BROWN FINTUBE (GREAT BRITAIN) LTD., BIRMINGHAM, ENGLAND • BROWN FINTUBE (CANADA) LTD., ST. THOMAS, ONTARIO, CANADA
FRIEDRICH UHDE, GMBH, DORTMUND, GERMANY



MIXING RESULT may be affected by many variables. But these variables can be correlated in one curve, permitting extrapolation to any size system.



JUST-RIGHT MIXING. Hundreds of power-speed combinations are possible with these LIGHTNIN Mixers—so you get the mixer that's exactly right for your needs. Turbine, paddle, and propeller types; for open or closed tanks. Sizes 1 to 500 HP.



MAKE ANY OPEN TANK an efficient mixing vessel, by adding a LIGHTNIN Portable Mixer. Thousands in use, many for 20 years and more. Thirty models, ⅓ to 3 HP.

IN LARGE TANKS (up to 6 million gallons) you can mix, blend, circulate, suspend solids efficiently with LIGHTNIN Side Entering Mixers. No shutdowns are ever necessary to repack stuffing box or replace mechanical seal. Sizes 1 to 25 HP.

How to **be sure you're right** *when you scale up a fluid mixing operation*

Your mixing operation may look good in a 10-gallon pilot tank.

But how can you be sure it will *still* look good when you scale it up to 10,000 gallons, 50,000 gallons, or 5 million gallons?

How can you know that one of many variables, perhaps too small to show up in a pilot run, won't sprout into a costly problem as you increase the size of the system?

You can *guarantee* that this won't happen to you—simply by specifying LIGHTNIN Mixers for all your fluid mixing operations. Here's why:

Every LIGHTNIN Mixer you buy is unconditionally guaranteed to do the job for which it is recommended. When you decide to mix with LIGHTNINS, you automatically relieve yourself of all responsibility for success of the installation.

No waiting for answers

You save time, too. The facts you need for most applications are on tap at MIXCO, ready for instant use. On many applications, you can get a guaranteed LIGHTNIN Mixer recommendation, delivery date, and firm price *by phone,* without waiting.

On *any* application, MIXCO engineers can quickly tell you how much horsepower you'll need, the right impeller size, speed, and design to get the results you want *in the time you want them.* Based on scientific selection and scale-up methods, these predictions are guaranteed 100% accurate.

How to get started right

Even on routine fluid mixing operations (and certainly on any job involving heat transfer, crystal size control, suspension of solids, gas-liquid or liquid-liquid contacting), give yourself the advantage of *knowing* you're right—before you begin.

To find out how easy it is, just call your LIGHTNIN representative. You'll see his name in your copy of Chemical Engineering Catalog. Or write us direct for specific information that fits your mixing needs.

Get these helpful facts on mixing: cost-cutting ideas on mixer selection; best type of vessel; installation and operating hints; full description of LIGHTNIN Mixers. Free—no obligation. Just check data you want, tear out and mail to us today with your name and company address.

- ☐ DH-50 and DH-51 Laboratory Mixers
- ☐ B-102 Top Entering Mixers (turbine and paddle types)
- ☐ B-103 Top Entering Mixers (propeller types)
- ☐ B-104 Side Entering Mixers
- ☐ B-107 Mixing Data Sheet
- ☐ B-108 Portable Mixers (electric and air driven)
- ☐ B-109 Condensed Catalog (complete line)
- ☐ B-111 LIGHTNIN Rotary Mechanical Seals

MIXING EQUIPMENT Co., Inc., 199-b Mt. Read Blvd., Rochester 11, N. Y.
In Canada: Greey Mixing Equipment, Ltd., 100 Miranda Ave., Toronto 10, Ont.

"Lightnin Mixers"

MIXCO fluid mixing specialists